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VOL. CLXXII JULY, 1911 No. 1

THE PRINCIPLE OF RELATIVITY.

BY

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EVERY notion in physics which is independent of the minute and infinitely complicated particulars of varying points of view may be called an invariant.[1] Thus the kinetic energy[2] of a body is an invariant, the temperature of a body is an invariant, the mass of a body is an invariant, the volume of a body is an invariant, the electric charge on a body is an invariant, and so on. This does not mean that these various things are invariable, it only means that they are independent of the point of view. A gallon of water is a gallon of water from whatever point of view, and water at 100° C. is a definite thing from whatever point of view.

Perhaps the most widely accepted invariant ideas are those

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[1] Consider the expression

$$(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2$$

in the Cartesian system of co-ordinates. This expression is equal to the square of the distance between two points, and the expression remains entirely unchanged in value however the axes of reference may be moved or turned. Similarly the differential expression for the square of the velocity of a body and the differential expression for the square of the acceleration of a body remain entirely unchanged when the axes of reference are moved or turned in any way. Such expressions are called *invariants*.

[2] Kinetic energy, temperature, mass and volume are not invariant if motion is purely relative as explained later.

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which refer to time and space. The distance from New York to Philadelphia is 90 miles, and it is scarcely conceivable that a person could be placed in a condition which would force him to change his mind and think of the distance as 89 miles. Every person on the earth is able to say "Now, it is mean noon at Greenwich," and it is scarcely conceivable that a person could be placed in a condition which would make such a statement lose its meaning. It is scarcely conceivable how two persons using the same clock could be placed under conditions which would lead them to different results when they measure a given interval of time. And yet all these curious anomalies must exist, that is, time and length must depend upon the point of view of the observer, if motion is purely relative. It is the object of this paper to describe certain experiments which seem to show that motion is purely relative, not only in a limited mechanical sense, but in any and every sense, and to explain why the above mentioned anomalies (and others equally curious) must exist if motion is purely relative.

A man draws a weight towards his breast, but, of course, the exertion required differs greatly according as the man lies with his face downwards (in which case he draws the weight upwards), or with his face upwards (in which case he draws the weight downwards), or whether he stands erect (in which case he moves the weight horizontally). The effort required to move the weight over a given distance is not invariant with respect to change of direction in space. The recognition of the force of gravity, however, gives to us earth dwellers a system of mechanics which is invariant with respect to change of direction in space. Thus, the effect produced on a body by a force is independent of the direction of the force, due allowance being made for the force of gravity. What is here stated would perhaps completely satisfy a dweller on a flat earth, but the mere recognition of the force of gravity is not sufficient to give to us dwellers on a spherical earth a system of mechanics which is completely invariant with respect to changing directions in space. Let any one consider what he thought when he was first told of the people who walk around on the other side of the world with their feet up against the ground and their heads hanging downwards towards the sky! Indeed the introduction of the Copernican system into astronomy represents perhaps the greatest step that has ever been made towards the formation of fundamental ideas of mechanical phenomena, ideas which are invariant with respect to varying points of view.

Every one appreciates the invariance of mechanical phenomena with respect to change of direction of the axes of reference as exemplified in the above discussion. Also every one has a fund of experience showing that mechanical phenomena are invariant with respect to uniform velocity through space. Thus the effect of the high velocity of the earth through space is insensible to us earth dwellers, and every one knows that the motion of a boat, if it is uniform, is imperceptible to a person in the boat if he does not look at some body outside the boat. Indeed it is generally conceded that uniform motion of a system cannot be detected by observations taken within the system by an observer who moves along with the system. The only way to perceive uniform velocity of a system is by reference to an outside system. That is to say, velocity is purely relative.

The postulate that velocity is purely relative is called the *principle of relativity*. This principle has been fully recognized in mechanics since the time of Huyghens, but it has not been hitherto recognized as applying to the phenomena of electricity and magnetism.

DOES THE PRINCIPLE OF RELATIVITY APPLY TO ELECTROMAGNETIC PHENOMENA?

Do the observable effects which are associated with electric charges, electric currents, and magnets depend upon the velocity of the system in which the effects take place, or does the principle of relativity apply to electromagnetic phenomena? In attempting to discuss this question one faces a very serious difficulty. Many of the phenomena of electricity and magnetism are not at all familiar. Indeed the one electromagnetic phenomenon which is familiar, the transmission of light, stands in most men's minds as an isolated fact, a fact which is not connected with any other observable effect whatever; and to say that light travels at a speed of 186,000 miles per second is to say that light transmission is not only beyond our native physical sense, but also beyond the reach of any but the most extraordinarily powerful physical imagination. To talk about the physical aspects of light transmission is to talk without sense to those who have had no experience in refined electromagnetic measurements, and it is to talk utterly without logical effect to those who have no ideas as to the electromagnetic character of light. There is no help in the face of such a difficulty but to assert the electromagnetic character of light as a fact which is as well understood as anything in physics, and to state that Maxwell's theory —as the almost completely consistent group of informing ideas in electromagnetism is called—has, with all leading physicists, acquired a force sufficiently compelling to turn them away from the classical ideas of mechanics, and make them give up the thousand-year-old ideas of time and space. A remarkable fate indeed of a theory which during the lifetime of its author no one understood!

There is indeed definite experimental evidence in favor of the extension of the principle of relativity to include electromagnetic phenomena as well as mechanical phenomena, and a necessary consequence of this extension of the principle of relativity is an apparent perversion of our accepted ideas of space and time. We are forced to admit that it is not everywhere *now*,[3] and that *to-day* with us here is elsewhere *yesterday* or *to-morrow!* Surely a group of ideas which would force us to such a conclusion with increase of intelligence and unimpeached sense is worth talking about even if the details of Maxwell's theory be left out of the discussion.

SOME ELECTROMAGNETIC EFFECTS DEPENDENT ON MOTION.

A moving magnet exerts a propelling force on electric charge. This is exemplified in the ordinary dynamo in which a moving magnet causes an electric current to flow in a wire.

A moving electric charge exerts a force on a magnet. This is exemplified by the action of an electric wire on a compass needle. The moving charge in the wire (the electric current) exerts a force on the compass needle.

The above effects depend upon relative motion of two things, but the following effect is to be expected when two electric charges move along side by side. A moving charge is equivalent to an electric current. Therefore, two like charges, *QQ*, Fig. 1, moving along side by side are equivalent to two parallel currents in the same direction, and two such currents attract each other. Therefore the electrostatic repulsion of two like charges would be to some extent annulled by this current-attraction when the charges move along side by side. If the principle of relativity applies to electromagnetic phenomena, however, it would be necessarily impossible for an observer moving along with the two charges in Fig. 1 to detect any change in their repulsion.

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[3] Differences in local time as reckoned at different places on the earth are, of course, not here referred to.

No attempts have been made to detect the decreased repulsion of charges moving along side by side; the possible precision of force measurement is not great enough to make such an attempt worth while even though the experiments be arranged to make use of the very high velocity of the earth in its orbit.

FIG. 1.

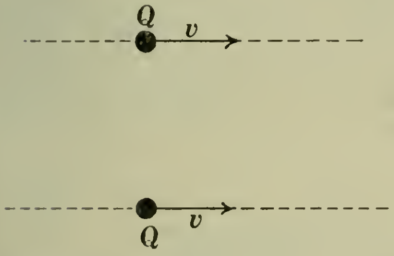
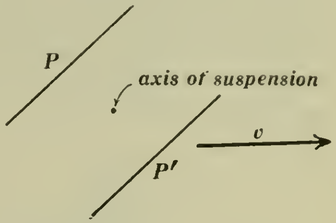


FIG. 2.



An electromagnetic effect in a moving system which is very closely related to the above and which would be easier to detect is as follows: Two insulated metal plates *P P′*, Fig. 2, are suspended by a quartz fibre. When the system travels at velocity v one would expect that the charging of the two plates *P* and *P′* would give the suspended system a rotational impulse. Experiments made by Trouton and Noble in 1904, show, however, that this effect is non-existent, as one would expect from the principle of relativity.

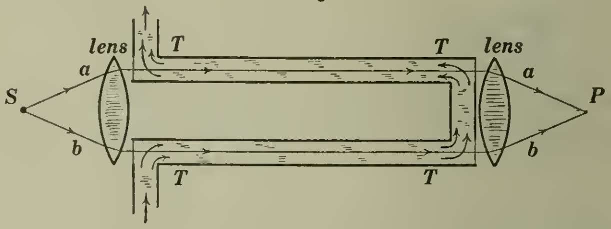
THE PRINCIPLE OF RELATIVITY AND THE TRANSMISSION OF LIGHT.

Certain well-known phenomena of light transmission depend upon the relative motion of two bodies. Thus the motion of the earth in its orbit causes an apparent motion of the fixed stars (astronomical aberration). The motion of a star towards the earth (or the motion of the earth towards a star) causes the lines in the star's spectrum to be shifted towards the violet (the Doppler effect).

Light has long been supposed to be a wave motion in a medium called the *ether*. If this is true then light must be thought of as having a definite velocity with respect to the ether of space just as sound has a definite velocity with respect to the air through which it travels. Therefore the velocity of light relative to an observer on the moving earth would be less in the direction of the earth's orbital motion than in the opposite direction; and an observer on the earth by determining the velocity of light in different directions could detect the motion of the earth. Such a result would be contrary to the principle of relativity and there are two related experiments which show that the apparent velocity of light does not vary with the velocity of the observer, namely the "experiment of Fizeau" and the "experiment of Michelson and Morley."

THE EXPERIMENT OF FIZEAU.—Water or air circulates through a tube *TT*, as shown in Fig. 3, and two beams of light *aa* and *bb* coming from the source *S* pass through the respective tubes and reunite at the point *P*. If the light-transmitting medium is carried along with the water or air in the tube, then the velocity of the beam *aa* with reference to the stationary parts of the apparatus would be $c - v$, and the velocity of the beam *bb* would be $c + v$, where c is the velocity of light in a stationary substance and v is the velocity of the fluid in the tubes *TT*. This difference in velocity would produce a certain retardation of the beam *aa* as compared with the beam *bb*, characteristic interference would be produced at the point *P*, and the relative retardation of the beam *aa* could be calculated from the observed character of the interference. Fizeau's experiment shows, however, that the light-transmitting ether is not[4] carried along with the fluid in the tube *TT*.

FIG. 3.



MICHELSON AND MORLEY'S EXPERIMENT.—Consider a light flash at the point *O*, Fig. 4, and let the circle *ww* represent the position of the light wave after one second. The radius c of the circle represents the velocity of light with reference to the stationary point O. Consider the point P which was at O at the instant of the flash but which moves to the right at velocity v so that after one second OP' equals v. The velocity of the light wave ww with reference to the moving point P is $c - v$ in the forward direction (to the right in Fig. 4), $c + v$ in the backward direction (to the left in Fig. 4), and $\sqrt{c^2 - v^2}$ in a direction at right angles to v (upwards or downwards in Fig. 4).

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[4] This statement is not quite complete. A full discussion of the experiments of Fizeau and Michelson and Morley is not here attempted. See Planck's *Acht Vorlesungen über theoretische Physik*, pages 111–116, 1910.

Now a device for comparing the velocity of light (in a laboratory) in a direction parallel to the earth's orbital motion ($c \pm v$) with the velocity of light in a direction at right angles to the earth's orbital motion ($\sqrt{c^2 - v^2}$) would enable an observer to detect the orbital motion of the earth in his laboratory, and indeed the comparison may be made *in* the laboratory because Fizeau's experiment shows that the ether is not carried along in a moving substance (laboratory walls and surrounding atmosphere).

FIG. 4..

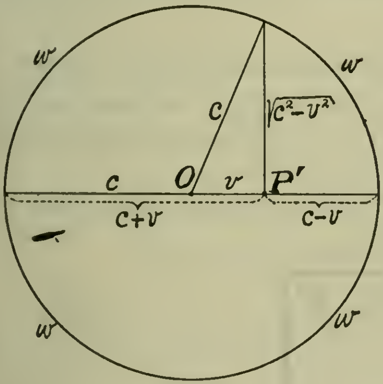
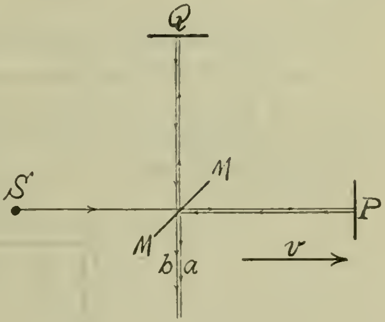


FIG. 5.



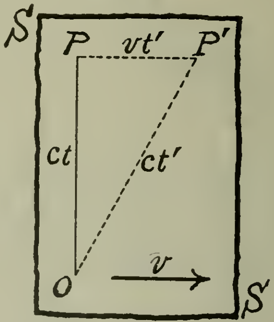
The arrangement used by Michelson and Morley for comparing the two velocities $c \pm v$ and $\sqrt{c^2 - v^2}$ is shown in Fig. 5. Light from the source S strikes a semi-reflecting mirror MM. Part of the incident light goes through MM, travels to the distant mirror P and back again and is then partly reflected downwards by the mirror MM as the ray a. The remainder of the incident light is reflected by MM, and after travelling to the mirror Q and back again it is partly transmitted by the mirror MM as ray b. If a longer time is required for the ray a to travel from O to P and back again than for the ray b to travel from O to Q and back again, then the two rays a and b will show characteristic interference, from which the difference of the velocities of light in the two directions can be calculated; but Michelson and Morley's results show that the influence of the observer's motion on the apparent velocity of light (see Fig. 4) is illusory, such an effect does not exist. In other words it takes light the same length of time to go from O to P and back again, as from O to Q, and back again (see Fig. 5) in spite of the orbital velocity, v, of the earth. All of this is in accord with the principle of relativity, and in the following section the invariance of the velocity of light (its independence of the velocity of the system in which it is measured) is used as a basis for the discussion of the remarkable Lorentz-Einstein transformation of time and space.

THE LORENTZ-EINSTEIN TRANSFORMATION OF TIME AND SPACE.

TIME.—Let t be the time required for light to travel from O to P in a stationary system SS, Fig. 6. Then the distance OP is equal to ct, where c is the velocity of light.

Imagine the whole system SS to be moving to the right at velocity v. Then light, in travelling from a moving observer at O to a moving observer at P, really travels from O to P'. Let t' be the time required for light to travel thus from O to P'. Then the distance OP' is equal to ct', the distance PP' is equal to vt', and from the right triangle OPP' we have

Fig. 6.



$$c^2t'^2 = v^2t'^2 + c^2t^2$$

or

$$(c^2 - v^2)t'^2 = c^2t^2$$

or

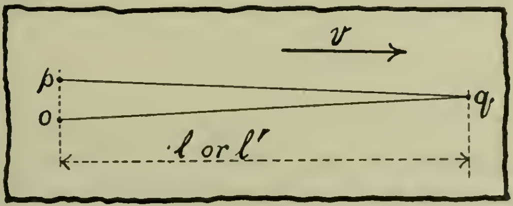
$$\frac{t}{t'} = \frac{\sqrt{c^2 - v^2}}{c}$$

But if motion is purely relative, it must be impossible for an observer moving with the system to perceive that the time t' is greater than the time t. That is to say, a moving observer would measure the greater time t' and find it the same in value as the stationary observer finds the lesser time t, and therefore the unit of time of the moving observer must be greater than the unit of time of the stationary observer in the ratio of

$$c : \sqrt{c^2 - v^2}.$$

SPACE.—Let l be the distance pq or qo in Fig. 7 when the system is standing still. Then the time, t, required for light to travel from a stationary observer at p to a stationary observer at q and back again to o is equal to the distance $2l$ divided by c, that is $t = 2l/c$.

FIG. 7.



Let l' be the distance between the observers at p and q when the whole system (including the observers at p, q and o) are moving to the right at velocity v. Then the velocity of light to the right (relative to the moving observers) is $c - v$, and the time required for light to travel from p to q is $\frac{l'}{c - v}$; furthermore the velocity of light to the left (relative to the moving observers) is $c + v$, and the time required for light to travel from q to o is $\frac{l'}{c + v}$. Therefore the time, t' required for light to travel from p to q and back to o is

$$t' = \frac{l'}{c - v} + \frac{l'}{c + v}$$

and by a simple algebraic transformation this gives

$$t' = \frac{2l'}{c} \cdot \frac{c^2}{c^2 - v^2} \qquad \text{(a)}$$

Now if motion is purely relative, the time t' as measured by the moving observers must be equal in *value* to $t\left(=\frac{2l}{c}\right)$ as measured by the stationary observers, but the time unit of the moving observers is greater than the time unit of the stationary observers in the ratio $c : \sqrt{c^2 - v^2}$. Therefore t', expressed in the time unit of the stationary observers is equal to

$$\frac{c}{\sqrt{c^2 - v^2}} \times t,$$

or to

$$\frac{c}{\sqrt{c^2 - v^2}} \times \frac{2l}{c}.$$

Placing this value of t' into equation (a) and reducing we have

$$\frac{l}{l'} = \frac{c}{\sqrt{c^2 - v^2}}.$$

That is to say, the distance l' is less than l in the ratio $\sqrt{c^2 - v^2} : c$. If motion is purely relative, however, it must be impossble for the moving observer to find a different value for l' than is found by the stationary observer for l. And therefore, the yard-stick in a moving system (when it is parallel to the velocity of the system) is shorter than it is in the stationary system in the ratio $\sqrt{c^2 - v^2} : c$.

This difference of time and space measurement in two systems, one of which moves with respect to the other, was discovered partly by Lorentz and partly by Einstein and it is called the Lorentz-Einstein transformation.[5]

Consider a stationary observer A and another observer B who is moving to the right at velocity v. In describing the space and time relations of A and B it is convenient in speakng of measurements to right or left as made by A as constituting

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[5] A good and simple mathematical discussion of this transformation is given by Planck in his *Acht Vorlesungen über theoretische Physik,* pages 118–122, Leipsig, 1910. These lectures were delivered at Columbia University in 1909.

"*A*'s space," and of measurements to right or left as made by *B* as constituting "*B*'s space." It is also convenient to speak of time "as reckoned by *A*" and of time "as reckoned by *B*." Space and time as measured and reckoned by *A* are represented by x and t, and space and time as reckoned by *B* are represented by x' and t'.

A complete picture of the Lorentz-Einstein transformation of space is shown in Figs. 8 and 9. Let us consider especially Fig. 8 which shows *B* travelling to the right through *A*'s space. The distance from *A* to any point *p*, as measured by *A*, is x; the distance from *A* to *B*, as measured by *A*, is vt, and the distance from *B* to *p*, as measured by *B*, is x'. The construction angle θ[6] is an angle whose cosine is $\sqrt{c^2-v^2}/c$.

FIG. 8.

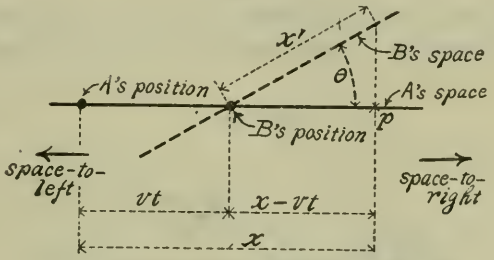
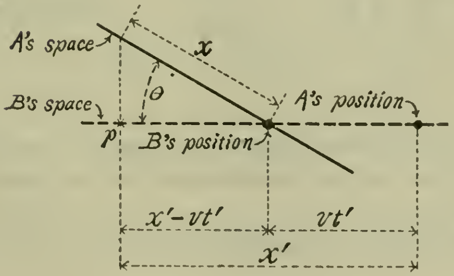


FIG. 9.



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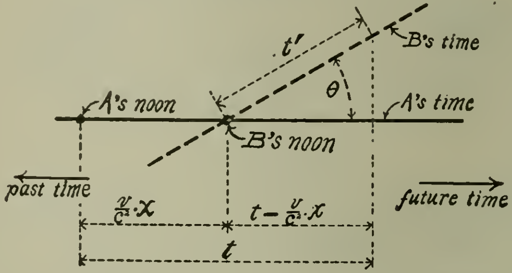
[6] Minkowski has shown that this angle θ is an angle of rotation of all space (x, y and z) about the plane yz in a fourth dimension. See *Physikalische Zeitschrift* 10, pages 104–111, February, 1909.

Observer B travels to the right through A's space at a velocity of v centimetres per second. This, of course, everyone understands; but the remarkable thing about the Lorentz-Einstein transformation (the necessity of which is explained in connection with Figs. 11, 12 and 13) is that we are forced to conclude that B also moves through A's time towards the future at the rate of $\frac{v}{c^2}$ seconds per centimetre. This transformation of time is shown from A's point of view in Fig. 10. Suppose A and B both reckon time from the instant that they pass each other, and let us call this instant "A's noon" and "B's noon." Then, when B has moved a distance x to the right, the instant which B reckons back to and calls his noon is $\frac{v}{c^2}\cdot x$ seconds after noon to A, and the instant which A reckons back to and calls his noon is Bq seconds before noon to B. Indeed x need not be a distance travelled by B; consider a place x centimetres to the right (or left) of A, it is $\frac{v}{c^2}\cdot x$ seconds after noon (or before noon) to A when it is noon *at that place* to B. When it is everywhere "now" to A it is not everywhere "now" to B; that is two events which are simultaneous to A are not simultaneous to B if they are at different places.

Fig. 10.



PARALLEL STATEMENTS REFERRING TO FIGS. 8 AND 10.

At a *time* *t seconds* *later-than* *A's noon*
At a *place* *x centimetres* *to-the-right-of* *A's position*

in Fig. 8, B has penetrated vt *centimetres* into A's
in Fig. 10, B has[7] penetrated $\frac{v}{c^2}\cdot x$ *seconds* into A's

space-to-the-right,
future,

or with reference to B's space-frame, A has penetrated
or with reference to B's time-frame, A has[7] penetrated

into B's *space-to-the-left.*
into B's *past.*

Everyone, of course, realizes that it is not everywhere "here," and however far a moving object may be at a given instant it will be "here" "then" if *then* is late enough; so, in the new conception of time, it is not everywhere "now" but however early or late it may be at a given place in a moving system it will be[7] "now" "there" if *there* is far enough.[8]

The necessity of the above transformation of space and time may be explained[9] as follows: Consider a stationary observer A and another B who is moving steadily to the right at velocity v. Imagine a flash of light to be emitted by A or B at the instant that B passes A. After one second the light wave will have travelled a distance c in all directions from A, that is, the light wave will be a sphere of radius c with its centre at A, as shown in Fig. 11. Observer A considers observer B as not at the centre of this sphere because during the one second of time B has moved a distance v to the right (to B) as shown. If motion is purely relative, however, observer B would be justified in considering himself to be stationary and A as moving to the left at velocity v, and therefore, from B's point of view, the light wave must be a sphere of radius c with its centre at B, and of course, B would consider that A is not at the centre of this sphere.

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[7] There is no form of a verb which can be properly used here. Referring to Fig. 8 the form *has penetrated* is proper, but referring to Fig. 10 a form should be used which is related to space exactly as ordinary past tense is related to time. Thus in Fig. 8, B has moved vt centimetres to the right during the time t, whereas in Fig. 10 we may say that B "has moved" $\frac{v}{c^2} \times x$ seconds into A's future; but no time has elapsed, only space x "has been" put behind.

[8] The similarity of space and time has been completely formulated by Minkowski in a paper that is rather difficult to read. See *Physikalische Zeitschrift,* February, 1909.

[9] The following discussion is not complete. See Planck's *Acht Vorlesungen*, pages 118–122.

If motion is purely relative, these two points of view (of observer A and of observer B) are equally correct; A waits one second after the light flash and measures out to the light wave finding it to be a sphere of radius c with himself at the centre. In the same way, B waits one second after the light flash and measures out to the light wave and he also finds the wave to be a sphere of radius c but with himself at its centre. It seems as though A and B must be in hopeless disagreement as to where the light wave is after one second. The only escape from this dilemma is to admit that the two observers differ from each other as follows:

1. They do not reckon the passage of time in the same way.
2. Events which are considered to be simultaneous by A are not simultaneous to B, and *vice versa*.
3. They do not measure space in the same way, and
4. They do not measure time in the same way.

Observer A, who thinks he is at rest, sees B's measuring stick shortened (when it is parallel to B's direction of motion), and B, who thinks he is at rest, sees A's measuring stick shortened (when it is parallel to the direction of A's motion).

Fig. 11 represents the light wave in A's space after one second as reckoned by A, and Fig. 12 shows the light wave in B's space after one second as reckoned by B. The circle in Fig. 13 shows the light wave in A's space after the lapse of 1.154 seconds as reckoned by A, and the ellipse shows the light wave as measured by A when *at each point of the wave* it is one second after B's noon as reckoned by B. The ellipse is, of course, in A's space inasmuch as it is measured by A; but as seen by B the ellipse is shortened in the direction of the motion of A with respect to B, and it becomes a circle as shown in Fig. 12, with B at its centre.

Our experience has not supplied us with a ready-made sense-frame, or aperceptive complex, or intuition or what-you-may-call-it whereby we can see things in the unusual way represented by the Lorentz-Einstein transformation. Indeed, taking *A*'s point of view we can understand *B*'s point of view as a delusion but not otherwise, although *B*'s point of view is as legitimate as our own (*A*'s) and we would accept it as our own if we were in *B*'s place and then we would consider *A*'s point of view as a delusion. Perhaps *A* may sometime discuss

FIG. 11.

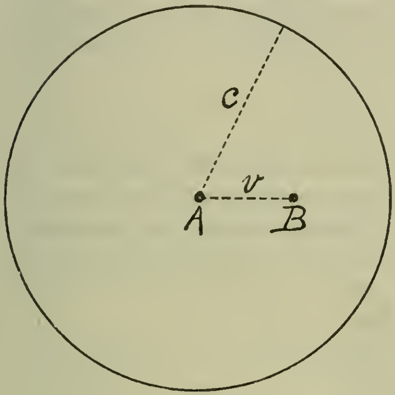


FIG. 12.

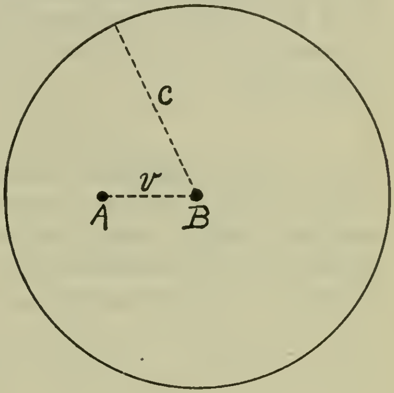
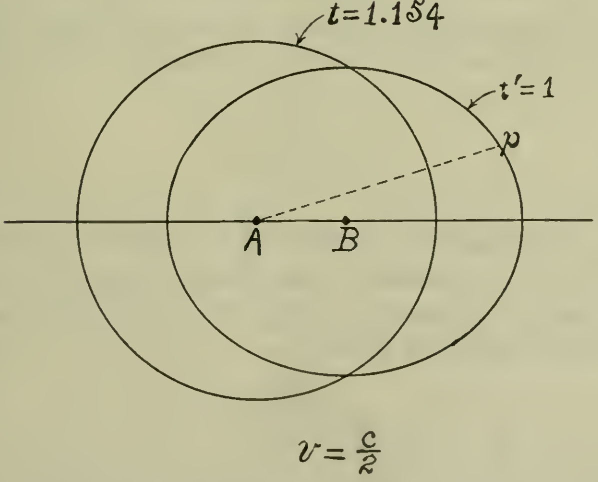


FIG. 13.



the matter with B and settle the question. Well, it is pretty nearly settled already by the experiment of Trouton and Noble and by the interferometer experiment of Michelson and Morley, to say nothing of such indirect evidence as the light-pressure experiment of Nichols and Hull.[10] Indeed the direct experimental evidence of the principle of the conservation of energy is at the present time nearly as inconclusive as the direct experimental evidence of the unconditional validity of the principle of relativity.

THE NEW MECHANICS.

A very remarkable consequence of the extension of the principle of relativity to include electromagnetic phenomena is that the familiar ideas of mass and kinetic energy are curiously altered.[11] The momentum, G, of a moving body is not given by the familiar expression $m_0 v$ but by

$$G = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

The quotient $\frac{G}{v}$ is called the *transverse mass* of the body because it measures the inertia of the body with respect to change of direction of v (sidewise acceleration), and it is equal to

$$\frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

On the other hand the quotient $\frac{dG}{dv}$ is called the *longitudinal mass* of the body because it measures the inertia of the body with respect to a change in value of v (forward or backward acceleration) and it is equal to

$$\frac{m_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{3}{2}}}.$$

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[10] See a very simple paper by G. N. Lewis, *Philosophical Magazine*, vol. 16, pages 705-716, November, 1908.

[11] The simplest discussion of this subject is given by G. N. Lewis, *Philosophical Magazine*, vol. 16, pages 705-717, November, 1908, and by Lewis and Tolman, *Philosophical Magazine*, vol. 18, pages 510-523, October, 1909.

In general therefore the mass of a body depends on its velocity, and the above expressions have been quite accurately verified by experiments of Bucherer and of Hupka on the magnetic deflection of moving electrons.

The familiar expression for the kinetic energy of a moving body is $\frac{1}{2}m_0v^2$ whereas the electromagnetic theory and the principle of relativity lead[12] to

$$W = m_0c^2 + \tfrac{1}{2}\, m_0v^2 + \cdot \cdot \cdot \cdot$$

This equation is in substantial agreement with the electron-theory of mass.

It is not the purpose of this article to discuss the recent theories of mass and energy, and the above very meagre statements are introduced in order to bring out a very important matter discussed by Planck.[13] If motion is purely relative mass cannot be considered as a fundamental idea in mechanics, because it is a variant; and the older philosophy of physics which rests upon the fundamental postulate of definite mass-particles in motion is untenable. This older philosophy of physics attempted to reduce every phenomenon to a "mode of motion" in the familiar mechanical sense of this term, and if motion is purely relative this reduction is impossible because the thing that moves loses its identity (becomes a variant).

IS THE IDEA OF TIME AS A STEADY UNIVERSAL FLUX A LEGITIMATE IDEA?

Consider a purely mechanical system (one in which no irreversible action takes place). Any change of this system after a lapse of what we call time can be completely specified in terms of the positions and the velocities of the component parts of the system without any reference whatever to the time which has elapsed since the beginning. Therefore, to say that time has elapsed is to introduce an arbitrary and meaningless difference between the initial and final states of the system in addition to the differences already completely specified in mechanical terms. It seems, of course, absurd to make this statement because every one realizes in looking at the ideal mechanical system that time has elapsed between its initial state and final state; but this view of the matter involves the inclusion in our ideal system of one's own physical body and the projection of one's own consciousness into the aggregate of phenomena under consideration. Let us, therefore, consider our ideal system apart from its relation to any outside condition whatever. Then, to say that time has elapsed is to introduce an arbitrary and meaningless difference between the initial and final state of the system.

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[12] The first term of this expression is derived by Lewis from simple considerations of light pressure. See *Philosophical Magazine*, vol. 16, pages 706-708.

[13] See a remarkable address by Planck in *Physikalische Zeitschrift*, 11th year, pages 922-932, November, 1910. This address of Planck and Larmor's discussion of the limitations of mechanical explanation (see Larmor's *Aether and Matter*, Appendix B, Cambridge University Press, 1909) are the most complete statements hitherto made concerning the significance of the classical mechanics. The classical mechanics is limited in another direction by thermodynamics as explained in a very simple way by the present writer in an article entitled "The Second Law of Thermodynamics: Its Basis in Intuition and Common Sense"; see *Popular Science Monthly*, March, 1910.

Consider a system in which irreversible processes take place. Such a system departs farther and farther from its initial condition without possibility of return, but in this case a complete specification of the change in the system can be made in terms of mechanical specifications and entropy specifications, and it would seem to be meaningless to add a further specification of lapse of time to what is otherwise complete.

What we call time, when reduced to its simplest terms, is a phenomenon of consciousness, and our sense of the inevitable forward movement of time is dependent upon the existence of irreversible processes everywhere about us and especially inside of us. That is to say, our sense of the forward movement of time and the law of increase of entropy are based upon or grow out of the same fundamental condition of nature. It would seem, therefore, that the universal steady flux of time is an idea, not a physical fact, although, taking the universe as a whole, local irregularities become individually negligible and the entire process of nature may be thought of as one vast steady sweep in which increase of entropy and passage of time, much as they differ in our local methods of measuring them, refer fundamentally to the same thing.

The extent to which the idea of the steady flux of time prevades our habitual modes of thought is the outgrowth of the methods we have come to use in the expression of our rather complicated experiences relating to what we call coincidences in time. Indeed some of the most pervasive things of the human mind are ideations which have been developed in connection with language, and to make due allowance for them in a physical discussion is sometimes very difficult indeed. partly because we fail to recognize the ideations as such and partly because we are left without adequate forms of expression if we set them aside. We always make time specifications with respect to a recurrent phenomenon like the rising of the sun, with finer gradations based upon the oscillation of a pendulum; our time specifications are simple counts of these recurrent phenomena; and the requirements of simplicity and directness of speech have led to the idea of the steady flux of time and to the habitual projection of this idea into every objective condition we encounter in nature.

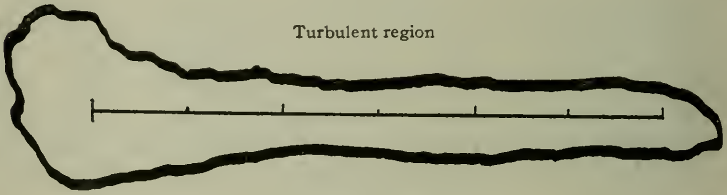
Two phases of two systems are simultaneous or coincident in time when they involve the loss of energy by one of the systems and the gain of energy by the other system. Thus the idea of simultaneity rests fundamentally upon the principle of the conservation of energy. If energy could be taken from one system, temporarily annihilated, and later delivered to another system, our idea of simultaneity would have to be modified; or if energy is taken from one system and if some time must elapse before it is delivered to another system, as in the case of transmission of energy by a beam of light, then again a modified conception of simultaneity would have to be developed. Indeed this modified idea of simultaneity is already accomplished in terms of the idea that light has a definite velocity. It seems, however, that light does not have a definite velocity in the simple mechanical sense of the term velocity, and if so we are forced to the idea of simultaneity which is involved in the Lorentz-Einstein transformation.

The idea that it is everywhere *now* cannot be justified in the physical nature of things although an assumption to that effect is extremely convenient in speech. Also the idea that time is a universal steady flux cannot be justified in the physical nature of things although an assumption to that effect is extremely convenient in speech. Indeed, throughout the above discussion, modes of expression are used which involve the common idea of time as a steady flux and to avoid the use of these common modes of expression would make the discussion extremely difficult to follow.[14]

THE IDEA OF SPACE.

Our idea of extension in space is undoubtedly based upon measurement, and perhaps the rough measurement by steps in walking is the kind that has had most to do with the growth of our idea of space. If we wish to subject our idea of space to criticism, however, we must consider the most careful of length measurements, and such measurements are limited in precision by the turbulence of the material through which and by which the measurements are made. In a certain strict sense a turbulent region has no dimensions, to attempt to measure such a region a quiescent region must be projected into it as indicated in Fig. 14. This matter may be more clearly illustrated by Fig. 15 which represents a turbulent region surrounded by a quiescent shell. The turbulent region has no volume, to measure what we would call its volume all of our measurements would be made on or in the shell and therefore the cubic contents or volume is a property of the shell.

FIG. 14.



Measurements of length beyond the range of the yardstick are made indirectly, by triangulation, and lines of sight are always used in such work. No one can therefore deny that space so measured must be subject to all the peculiarities of light transmission. If light transmission requires the shortening of space in a moving system in a direction parallel to the motion; why, then space is thus shortened and that is all there is to it. At least that is all there is to the question of shortening of triangulated space. As to the shortening of *B*'s yardstick in Figs. 8, 9, 10, 11, 12 and 13, this again is largely a question of what *A* sees and that settles it.[15]

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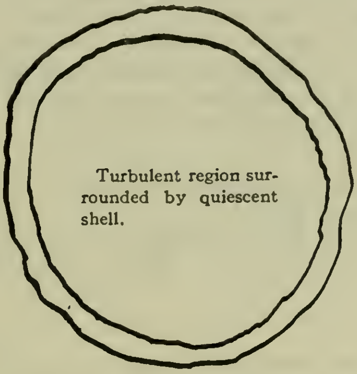
[14] In this discussion of time we have left untouched the question as to what may be the physical differences in nature which correspond to passage of time. This matter is discussed by the present writer in a brief paper entitled, "Entropy and Time," in *Physical Review*, vol. xxx, pages 766–775, June, 1910.

FIG. 15.



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[15] This matter is discussed rather minutely by G. N. Lewis and R. C. Tolman, *Philosophical Magazine*, vol. 18, pages 510–523, October, 1909.

Petroleum Production of the United States in 1910. Oil, Paint and Drug Rep. (From *U. S. Geol. Surv. Bull.,* Jan. 30, 1911.)—In the year 1910, new oil supplies have been developed in the United States, more than enough to keep up the country's production of the last three years. The production increased to over 200,000,000 barrels, which is two-thirds of the world's supply and several million more barrels than the whole world produced seven years ago. The greatest developments were in the Sunset-Midway district of California, and in the Caddo field of Louisiana. Both these developments caused important changes in the conditions of marketing the oil. The total production as reported by D. T. Day, of the U. S. Geological Survey, was about 200,000,000 to 208,000,000 barrels, approximately distributed as follows:

Illinois	32,000,000
Appalachian and Lima (Indiana) fields	32,000,000
Gulf and Caddo fields	14,000,000
Mid-continent and Rocky Mountain fields	53,000,000
California	73,000,000
	204,000,000

Stocks increased over 50 per cent. on the Pacific coast. Prices of crude oil declined, except in the mid-continent field, where they increased to 44 cents a barrel.

The following figures show the exports of mineral oils:

	Gallons, 1909	Gallons, 1910
Crude	128,239,923	119,630,159
Illuminating	1,039,742,219	932,343,617
Naphtha	57,555,061	79,059,528
Lubricating and paraffin	157,147,914	158,866,676
Residuum	114,109,989	107,095,460
Total	1,496,795,106	1,396,995,440

Chromax Bronze, a New Alloy. Anon. (*Metal Ind.,* ix, 41.)—This is an alloy of chromium, copper and nickel. It is claimed to be the only copper alloy which contains chromium, and is protected by patents. As chrome-nickel-steel is recognized as the best steel, so this bronze is claimed to be superior to any other. As a bearing metal it is said to be unrivalled, and it has a high fusing point of 1200° F. It will not fuse nor cut even if raised to red heat by friction. It will stand 20,000 pounds pressure per sq. inch on a 6-inch bearing surface at slow speed. It takes on a high polish and will not crystallize. It has a tensile strength of 79.000 pounds per square inch with an elongation of 3.3 per cent. and is extremely dense. It is acid proof, non-corrosive and is not affected by seawater. It can be rolled into sheets and wire.

ON THE DURATION OF ELECTRICAL CONTACT BETWEEN IMPACTING SPHERES.

BY

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AND

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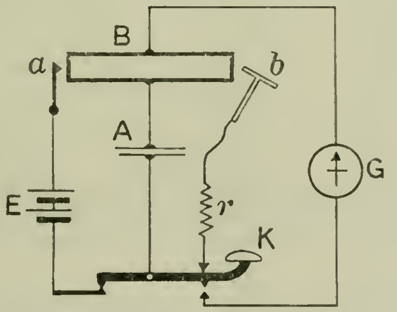
IN the *Philosophical Magazine* for May, 1876, Mr. Robert Sabine described "A Method of Measuring very small Intervals of Time," involving the determination of the loss of charge from a well insulated condenser through a non-inductive path of known resistance, closed for the very brief interval to be measured. In particular, the time of contact of a light hammer impacting on an anvil was measured in this way. Fig. 1, which is taken from that paper, represents at *B* a block of metal, or anvil, against which the contact, *a*, is pressed, in order to charge the condenser *A* from the battery *E*. The light hammer, *b* (weighing about 30 grammes), is then suddenly struck against *B* and allowed immediately to rebound. During the interval of contact between *B* and *b*, the condenser leaks through the resistance *r*, and the charge remaining in the condenser is measured by depressing

FIG. 1.



Connections of Sabine's apparatus for measuring the duration of impact between hammer and anvil.

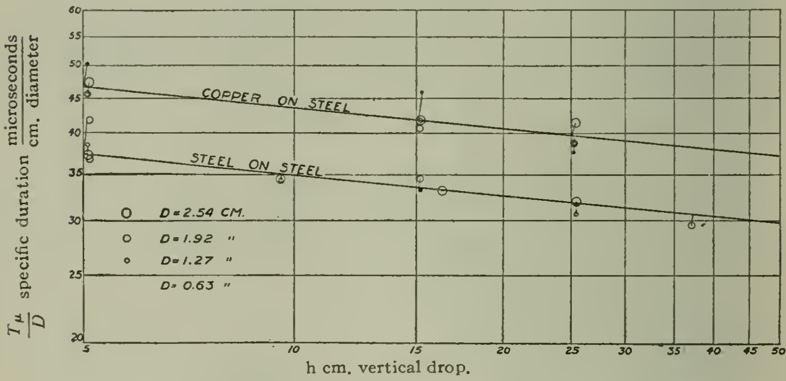
the key K and noting the deflection on the scale of the ballistic galvanometer G.

The formula applying to such a case is well known to be:

$$t = cr \log_e \left(\frac{Q}{q} \right) \qquad \text{seconds, (1)}$$

where Q is the intitial charge of the condenser in coulombs, q the charge remaining after the impact, c the capacity of the condenser in farads, and r the resistance of the discharging circuit in ohms. In the particular instance cited by Sabine $c = \frac{1}{3} \times 10^{-6}$ farad, $r = 1000$ ohms, $Q / q = 1.163$, $\log_e 1.163 = 0.151$, and $t = 0.000050$ second or 50 microseconds.

FIG. 2.



Graphs of observations on the specific duration of contact between copper balls and also steel balls impinging on a steel anvil, in four different sizes of balls. Ordinates specific duration $\frac{T\mu}{D}$. Abscissas, height from which the balls dropped. Logarithmic co-ordinates. Sets 1 and 2, Table I.

This Sabine apparatus was exhibited in London in 1876, and its operation witnessed by the first of the present writers, who repeated the experiments in February, 1889, using, however, a number of metallic spheres of different sizes and substances, in place of a hammer. A fine copper wire was fastened to the sphere under test, which was then dropped on the upper hardened steel surface of an anvil from a measured height. As in the Sabine experiment, a ballistic galvanometer was used to measure the condenser charges Q, q, before and after impact. The results obtained are given for the steel and copper balls in Table I and in Fig. 2. The results with the balls of other metals were very irregular, apparently owing to permanent deformation under the impact stresses, and are omitted. The last column in Table I gives the ratio of the computed duration of impact in millionths of a second to the diameter of the ball in cm. This ratio may be called the "specific duration." It will be seen that the duration was at least very nearly proportional to the ball's diameter at any given drop or height from which the ball fell upon the anvil, and also that the greater the drop, the shorter the duration, but that increasing the drop five times only decreased the duration about 16 per cent. The durations with the copper balls were all about 25 per cent. greater than with the steel balls, for the same diameter and drop; and

TABLE I.

MEASUREMENTS IN SERIES 1. OBSERVER K.

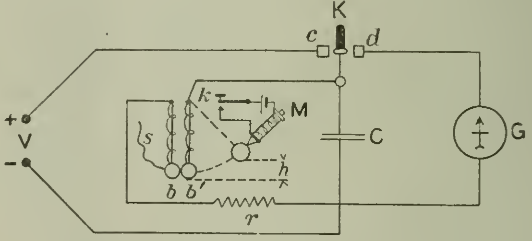
Ball number	Set number	Metal	Ball diameter, D., cm.	Drop, cm.	Impact duration, T_μ microseconds	Specific duration, $\frac{T_\mu}{D}$ $\frac{\text{microseconds}}{\text{diameter}}$
1	1	Steel	2.54	5.1	94.5	37.2
				9.7	87.5	34.5
				16.3	84.0	33.1
				25.4	81.0	31.9
2	1	Steel	1.92	5.1	70.5	36.9
				15.2	66.3	34.6
				37.0	56.5	29.5
3	1	Steel	1.27	5.1	49.0	38.6
				9.7	44.0	34.6
				25.4	39.0	30.7
4	1	Steel	0.63	15.2	21.0	33.1
				25.4	20.0	31.5
5	2	Copper	2.54	5.1	120.0	47.2
				15.2	106.0	41.7
6				25.4	106.0	41.7
	2	Copper	1.92	5.1	80.0	42.0
				15.2	77.0	40.4
				25.4	74.0	38.9
7	2	Copper	1.27	5.1	58.0	45.7
				15.2	53.0	41.7
				25.4	49.0	38.6
8	2	Copper	0.63	5.1	32.0	50.4
				15.2	29.0	45.7
				25.4	24.0	37.8

the durations also were more irregular with copper than with steel balls, apparently owing to the softer quality of the metal. If the copper balls fell from a height exceeding 20 cm. they were liable to become dented, or permanently deformed.

The above results were not published at the time; but were briefly described in a lecture given by the first writer at Cornell University in 1891, at which lecture the second writer was present. The fact was noted that the duration of impact increased with the size of the ball; but was not much influenced by the drop; or, therefore, by the velocity at impact, within the range here considered.

In October, 1910, the second writer set up the apparatus, for making the measurements as a laboratory class-room exercise, except that instead of using a ball impinging on an anvil, two similar and equal balls were suspended in such a manner that one was allowed to impinge on the other, as shown diagrammatically in Fig. 3. The balls *b b′* were of smooth hard steel, like bicycle balls, each having a diameter of 5.08 cm., a mass of 538.6 grammes and, therefore, a density of 7.865. The releasing electromagnet *M* was held in a clamp, and could be set at any desired position. With key *k* closed, the magnet would support ball *b′* at any desired height *h* cm. above its lowest position. On opening the key *k*, the ball *b′* would be released, would swing down against ball *b*, and, on colliding, come to rest; while ball *b*, after the impact, would take up the motion of *b′*. It was prevented from swinging back and striking *b′* a second time by being held up with the silk string *s; r* was an accurate, non-

Fig. 3.



Connections of apparatus in second series of tests.

inductive resistance which could be given various values. C was a high-grade mica condenser of one microfarad. G was a ballistic galvanometer. It was proved by careful experiment to give throw deflections over its entire scale which were closely proportional to the quantity of electricity discharged through it. Calling a deflection of 262 scale divisions the standard deflection, the percentage errors for other deflections were as follows:

Divisions, deflections.	Per cent. error.
105	—.40
157	—.33
262	0
314	—.3
366	—.36
418	—.23
460	—.06

It was therefore considered, in view of the nature of the experiment, and other sources of error, that the galvanometer throws might be accepted as proportional to the electric quantities discharged. K was a highly insulated key, which would charge C when the lever made contact with c, insulate C when it was in its midway position, and discharge C through the galvanometer when it made contact with d.

TABLE II.

SET NO. I. OBSERVER N.

Height constant at 2.01 cm. Resistance varied. Condenser charged to 4 volts.

Discharge resistance, ohms r.	d_1	d_2	Duration of contact, seconds	Specific duration, microseconds, $\frac{T_\mu}{D}$
200	423.5	190.5	.0001598	31.45
500	423.5	307.4	.0001600	31.49
1000	423.5	359.7	.0001620	31.89
5000	423.5	409.5	.0001680	33.07

All connections needing high insulation were made with wires in air and supported on glass rods. The condenser was charged first to 4 volts, then immediately discharged, and the throw of the galvanometer noted. This was repeated, but with the condenser left insulated for sixty seconds. The leakage of the condenser and wiring was thus found to be too small to require consideration.

After this preliminary work, two sets of measurements were made—set number one (Table II), in which the height of fall of the ball b' was kept constant, the resistance r varied, and the corresponding time of impact calculated, and set number two (Table III), in which r was kept constant at 500 ohms, and the height through which b' fell varied and the corresponding times of impact calculated. These heights, through which b' fell, were all measured with sufficient precision by means of a cathetometer. All measurements of throw deflections were repeated for each resistance and each height about ten times, and the means taken.

TABLE III.

Set No. 2. Observer N.

Resistance constant at 500 ohms. Height varied. Condenser charged to 4 volts.

Height in cm. h	d_1	d_2	Duration of contact, seconds	Specific duration, microseconds, $\frac{T_\mu}{D}$
43.48	424.7	334.6	.0001192	23.46
25.46	424.7	327.2	.0001304	25.46
8.41	424.7	317.3	.0001458	28.70
3.96	424.7	308.3	.0001602	31.58
1.92	420.7	300.8	.0001677	33.01

The times of impact were all calculated by relation (1) modified as follows, so as to give numerical results easily.

$$T_\mu = 2.3026\, r C_\mu \, log_{10} \frac{d_1}{d_2} \qquad \text{microseconds.} \quad (2)$$

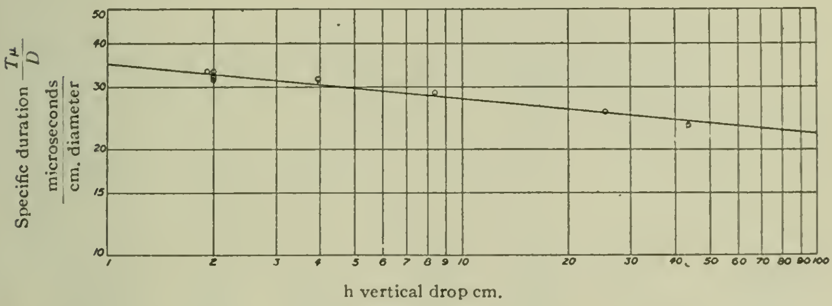
In (2) r is in ohms, C_μ is in microfarads, and equalled 1 microfarad; d_1 was the throw deflection with voltage to which the condenser was charged and then immediately discharged, the balls not having been in contact, d_2 was the throw deflection, the condenser having been charged to precisely the same potential, and then immediately discharged, but after the balls had collided.

The potentials applied to the condenser were at all times very accurately known, being determined with a potentiometer.

Tables II and III with the curve in Fig. 4 give all the essential facts brought out by the series of experiments.

The results recorded in Table III indicate that the duration of impact is distinctly increased as the height and impinging velocity of the falling ball are decreased. It was supposed that this conclusion might not be in conformity with the conclusions of the first writer. A comparison was therefore made, jointly, of the new sets of observations with those made in 1889. It was found that when both sets were marked off graphically on logarithm paper, as in Figs. 2 and 4, with abscissas of $log_{10}\ h$ and ordinate $log_{10}\ (T_\mu/D)$ they agreed in giving substantially straight-line graphs, descending 1 unit in ordinate to 10 in abscissas, or corresponding to the general formula:

FIG. 4.



Graph of observations on specific duration of contact between steel balls impinging on steel balls. Ordinates specific duration $\frac{T_\mu}{D}$. Abscissas, height from which the balls dropped. Logarithmic co-ordinates. Sets 1 and 2, Tables II and III. Diameter of balls, 5.08 mm.

$$\frac{T_\mu}{D} = \frac{a'}{h^{\frac{1}{10}}} \qquad \frac{\text{microseconds}}{\text{cm. diam.}} \qquad (3)$$

Doubling the vertical drop of the impacting sphere thus increases the duration of impact only $\frac{1}{2}^{\frac{1}{10}}$ or 7.16 per cent.

In view of the above substantial coincidence of results between series 1 and 2, both as to the effect of the duration of varied diameter, and as to the effect of varied height, the latter relation being apparent for the first time, it was decided that a third series of observations should be made with increased care, and the second writer undertook this experimental work.

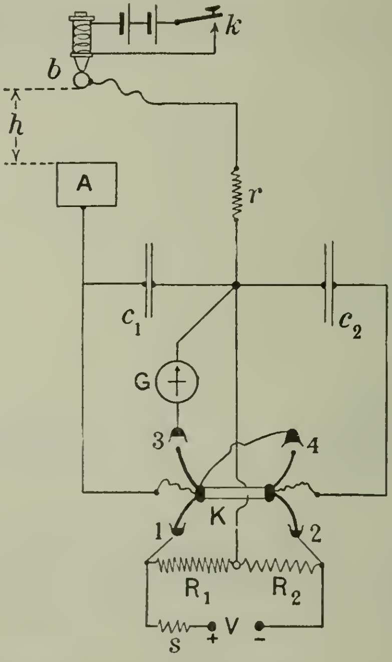
This work was made possible through the facilities provided by the Palmer Physical Laboratory, Princeton, N. J.

The experiments of the first writer were made with the facilities of Mr. T. A. Edison's laboratory.

DETAILS OF THE THIRD SERIES OF OBSERVATIONS.

Seven sizes of hard polished steel balls were prepared between the diameter limits of 2.54 and 6.35 cm. (1 in. and 2½ in.). The impact was made in the first set of measurements between pairs of equal balls with constant drop, in the second set between pairs of equal balls with different drops, and in a third set, between a ball and a mass of hard steel armor plate 33 x 33 x 22.9 cm., weighing 191.6 kg. In a short fourth set, a ball was dropped on a hardened steel anvil weighing 45.3 kg.

FIG. 5.



Connections of apparatus in third series of tests.

The measurement of the loss of charge during impact was made in all cases by the method of charge mixture, instead of by ballistic galvanometer deflections, so as to substitute a null method for a deflection method. That is, the charge left in the condenser after the impact was nearly neutralized by mingling it with a suitable known charge of opposite sign, the small residue of incomplete neutralization being then measured by the galvanometer.

The connections for the test are indicated in Fig. 5. c_1 and c_2 are two nearly equal condensers of accurately known capacity (0.5 microfarad); r is the adjustable, non-inductive resistance in the discharging circuit, A the block on which the ball, b, impinges. The rocking switch, K, when turned downwards as shown, charges the two condensers to potentials of opposite sign with quantities directly proportional to R_1 and R_2. These resistances were so adjusted that the value in ohms of the discharge resistance should be ten times the duration of the impact in microseconds, subject to a small correction for any residual discharge.

TABLE IV.

SET No. 1. OBSERVER N.

Height of fall constant at 10 cm. One steel ball strikes another of the same size, as in Fig. 3. Discharge connections as in Fig. 5.

Diam. of balls, D cm.	Disch. res., r ohms	Time, microseconds, T_μ	Specific duration, $\frac{T_\mu}{D}$	Specific duration referred to $h = 1$, $\left(\frac{T_\mu}{D}\right)_{h=1}$
2.54	716	71.57	28.18	35.47
3.175	893	89.0	28.03	35.28
3.81	1075	107.5	28.21	35.51
5.08	1402	140.2	27.60	34.74
			Mean 28.005	Mean 35.25

On throwing over the rocker slowly, the two condenser charges were first mingled through contact 4, and then the residue was discharged through the galvanometer by contact 3.

Third Series, First Set.—Table IV records the mean of observations on the duration of impact between balls of the same size, for pairs of different diameters, and with constant height of fall. It will be seen that the specific duration (T_μ/D), is nearly constant.

Third Series, Second Set.—Table V contains the results of a series of measurements with one pair of steel balls 5.08 cm. in diameter, one ball being suspended at rest, and the other allowed to impinge, by swinging against it from a measured height.

Third Series, Third Set.—In this set the connections were the same as in Fig. 5. Seven different sizes of steel balls were dropped from the same height (25 cm.) upon the bright surface of a mass of hardened steel armor plate 33 x 33 x 33.9 cm. weighing 191.6 kg, so as to rebound after a single impact. The observations are recorded in Table VI.

TABLE V.

Set No. 2. Observer N.

Duration and Specific Duration of Impact between two hard steel balls each 5.08 in diam., one being allowed to swing against the other from different elevations.

Vertical drop, h cm.	Resistance in disch. contact, r ohms	Galv. sensibility, divs. per ohm.	Duration of contact, T_μ microseconds	Specific duration of contact, $\frac{T_\mu}{D}$ $\frac{\text{microseconds}}{\text{cm. diam.}}$
0.002	3800.0		380.0	74.8
0.1	2360.0	0.085	235.7	46.39
1.0	354.0	2.2	176.6	34.76
1.0	1800.0	0.13	179.0	35.23
1.92	1800.0		167.7	33.01
2.0	1682.0	0.14	167.9	33.05
3.96	1682.0		160.2	31.53
5.0	1541.0	0.16	153.9	30.29
8.41	1541.0		145.8	28.7
10.0	1402.0	0.26	140.2	27.6
15.0	1368.0		136.7	26.91
20.0	1316.0		131.7	25.92
25.0	250.5		126.0	24.8
25.0	1265.0	0.3	126.6	24.92
25.46			130.4	25.67
35.0	1254.0		125.5	24.70
40.0	1230.0		123.2	24.25
43.48			119.2	23.46

Third Series, Fourth Set.—In this set the connections were the same as in Fig. 5. Two different sizes of balls were dropped from the same height (25 cm.) on the hardened steel surface of an anvil weighing 45.3 kg. The surface of the anvil was harder than that of the armor plate used in the preceding set. The observations are recorded in Table VII.

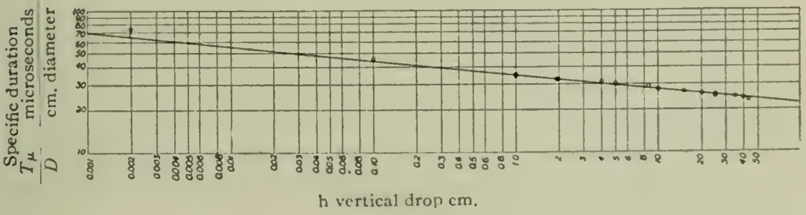
General Observations Concerning the Graphically Plotted Observations.—It will be observed that in each of the three series, the observations as plotted in Figs. 2, 4 and 6, substantially conform on logarithm paper to straight lines whose inclination is 1 in ordinates to 10 in abscissas. That is, the specific duration varies inversely as the $\frac{1}{10}$ power of the vertical drop. In the first series (Fig. 2), the deviations of the observations on either

TABLE VI.

SET NO. 3. OBSERVER N.

Diameter of falling ball, D cm.	Resistance in disch. circuit, r ohms	Galv. sensensibility divs. per ohm	Duration of impact $T\mu$	Specific duration, $\frac{T\mu}{D}$ $\frac{\text{microseconds}}{\text{cm. diameter}}$	Specific duration at 1 cm. $\left(\frac{T\mu}{D}\right)_{h=1}$ $\frac{\text{microseconds}}{\text{cm. diameter}}$
2.54	150.0	4.6	74.7	29.41	40.59
3.175	185.5	3.2	92.7	29.20	40.28
3.81	222.0	2.8	111.1	29.16	40.23
4.445	261.0	2.6	130.5	29.36	40.51
5.08	409.0	2.6	146.6	28.86	39.81
5.08	295.1	2.0	147.5	29.03	40.05
5.715	333.2	2.0	166.6	29.15	40.22
6.35	370.0	1.6	185.0	29.13	40.19
			Mean	29.16	Mean 40.23

FIG. 6.



Graph of observations on specific duration of contact between two hard steel balls, each 5.08 cm. in diameter, one being allowed to swing against the other from different elevations h cm. Ordinates specific duration $\frac{T\mu}{D}$. Abscissas elevation h. Logarithmic co-ordinates. Third series of measurements. Second set. Table V.

side of the straight line are appreciable, especially with some of the copper balls, and each recorded observation represents in most cases the mean of only two successive trials. In the second series (Fig. 4), the degree of precision was greater. The method of observation was the same as was used in the first series (ballistic galvanometer deflections); but more numerous trials were made in order to obtain each mean recorded observation. In the third series (Fig. 6), taken after this straight-line graph had been discovered, care was taken to subject this graph to a critical test. A null method was substituted for the deflection method of measuring, numerous observations were made for each point on the graph, and the range of vertical drop was increased (43.48:0.002 cm.). It will be seen that except at the lowest drop of 0.002 cm., where the precision in the drop determination is necessarily reduced, and where a magnetic attraction of the balls affected their velocity of approach, the agreement of all the points with the straight line of the $-\frac{1}{10}$ power is satisfactory. Table VIII collects the results of the different series of measurements.

TABLE VII.

SET NO. 4. OBSERVER N.

Diam. of falling ball, D cm.	Resistance in disch. circuit, r ohms	Galv. sensibility, divs. per ohm	Duration of impact, T_μ microseconds	Specific duration, $\frac{T}{D}$ $\frac{\text{microseconds}}{\text{cm. diam.}}$	Specific duration at 1 cm. $\left(\frac{T_\mu}{D}\right)_{h=1}$ $\frac{\text{microseconds}}{\text{cm. diam.}}$
2.54	151.6		75.8	29.84	41.17
5.08	308.0	2.24	154.0	30.315	41.83
				Mean 30.08	Mean 41.5

Possible Application of the Results.—Since it would appear from the above series of observations that the duration of contact between impacting steel spheres follows, at least approximately, a definite law between the range of 0.002 to 43 cm. for h, and of 0.63 to 5.08 cm. for diameter, the opportunity seems open to employ this result for obtaining definite and predetermined small intervals of contact in electric circuits under con-

TABLE VIII.

COLLECTING THE RESULTS OF THE DIFFERENT SERIES OF MEASUREMENTS.

Series	Date of series	Set	Observer	Nature of test	Table	Specific duration formula	Fig.	Range of h, cm.	Range of D, cm.
First	Feb. 1889	1	K	Steel balls on steel anvil	I	$44/h^{\frac{1}{10}}$	2	5 to 37	0.63 to 2.54
		2	K	Copper balls on steel anvil	I	$55/h^{\frac{1}{10}}$	2	5 to 25	0.63 to 2.54
Second	Oct. 1910	1	N	Steel ball on steel ball	II	$34.3/h^{\frac{1}{10}}$	–	2.01	5.08
		2	N	Steel ball on steel ball	III	$35/h^{\frac{1}{10}}$	4	1.9 to 43.5	5.08
Third	Feb. 1911	1	N	Steel ball on steel ball	IV	$35.25/h^{\frac{1}{10}}$	–	10	2.54 to 5.08
		2	N	Steel ball on steel ball	V	$35.0/h^{\frac{1}{10}}$	6	0.002 to 43.48	5.08
		3	N	Steel ball on steel armor plate	VI	$40.2/h^{\frac{1}{10}}$	–	25	2.54 to 6.35
		4	N	Steel ball on steel anvil	VII	$41.5/h^{\frac{1}{10}}$	–	25	2.54 to 5.08

ditions where the spark at rupture can be either eliminated or controlled. No attempt has, however, been made, as yet, by the writers to use the result in this way.

Relation between Specific Duration and Velocity at Impact.—If we take the duration of impact between two equal steel balls from Series II and III as:

$$T_\mu = \frac{35D}{h^{\frac{1}{10}}} \qquad \text{microseconds (4)}$$

and substitute for h its gravitational velocity $v\ \frac{cm.}{sec.}$ according to the well-known relation:

$$h = \frac{v^2}{2g} \qquad \text{cm. (5)}$$

where g is the acceleration due to gravitation in $\frac{cm.}{sec.^v}$ we obtain:

$$T_\mu = \frac{35D\,(2g)^{\frac{1}{10}}}{v^{\frac{1}{5}}} \qquad \text{microseconds (6)}$$

$$= \frac{35\,D\sqrt[10]{1962}}{v^{\frac{1}{5}}} \qquad \text{microseconds (7)}$$

taking $g = 981$ cm. per sec.² so that; since

$$\sqrt[10]{1962} = 2.1343,$$

$$T_\mu = \frac{74.7\,D}{v^{\frac{1}{5}}} \qquad \text{microseconds (8)}$$

or, in round numbers,

$$T_\mu = \frac{75\,D}{v^{\frac{1}{5}}} \qquad \text{microseconds (9)}$$

D ranging in the measurements from 0.63 to 5.08 cm., v from 2 to 292 cm. per sec., and T_μ from 20 to 380 microseconds.

Conclusions.—Within the limits of range and accuracy covered by the experiments, we may conclude as follows:

(1) If a metallic sphere impinges either upon another like metallic sphere, or upon a hard flat steel surface, the duration of impact is proportional to the diameter of the sphere.* Consequently, the duration per cm. of diameter or "specific duration"

---

* Although this experimental result has not previously been published, so far as the writers are aware, yet this particular fact seems not to be new. In particular, it has been known in the Jefferson Physical Laboratory, at Harvard University, for a number of years.

depends only on the nature and hardness of the metallic impacting surfaces, and on the velocity of impact. By referring then to specific duration, the influence of varying diameter, in what follows, can be eliminated.

(2) The harder the metals at their mutually impacting surfaces, the shorter the specific duration.

(3) The specific duration is roughly about 20 per cent. greater when a sphere impacts upon an anvil or stationary hard plane surface of a mass large as compared with that of the ball, than when it impacts with a stationary sphere of the same size. This increase in duration is attributable not only to the difference in relative curvature of the impacting surfaces; but also to the fact that in the former case the impinging ball has its velocity approximately reversed before breaking contact; whereas in the latter case the velocity of the impacting ball is merely reduced to zero, the initial velocity being communicated to the impacted ball.

(4) Whether the impacting ball strikes another like ball or an anvil, the specific duration of impact

$$\left(\frac{T_\mu}{D}\right)$$

varies inversely as the one-tenth root of the vertical drop h cm., or the one-fifth root of the impacting velocity, v cm. per sec. according to the formula:

$$\frac{T_\mu}{D} = \frac{a'}{h^{\frac{1}{10}}} = \frac{a''}{v^{\frac{1}{5}}} \ \frac{\text{microseconds}}{\text{cm. diam.}} \qquad (10)$$

where a' and a'' are constants depending on the nature and curvature of the impacting surfaces; such that

$$\frac{a''}{a'} = \sqrt[10]{2g} = 2.1343,$$

for $g = 981 \frac{cm.}{sec.^2}$.

For a copper ball on a steel anvil, $a' = 55$, $a'' = 117$ approximately.

For a steel ball on a steel anvil, $a' = 42$, $a'' = 90$ approximately.

For a steel ball on a steel ball, $a' = 35$, $a'' = 75$ approximately.

SYMBOLS EMPLOYED.

a', a'' = Constants in formula for specific duration.
c = Capacity of a condenser (farads).
C_μ = Capacity of a condenser (microfarads).
D = Diameter of sphere (cm.).
d_1, d_2 = Deflections of a ballistic galvanometer in discharging circuit (numeric).
e = 2.71828 .....
g = Gravitational acceleration $\left(\frac{cm.}{sec.^2}\right)$.
h = Height of descent of a sphere before impact (cm.).
Q = Initial charge of a condenser (coulombs).
q = Residual charge of a condenser (coulombs).
r = Resistance in discharging circuit (ohms).
t = Duration of partial discharge of condenser (seconds).
T_μ = Duration of partial discharge of condenser (microseconds).
v = Velocity of sphere at impact $\left(\frac{cm.}{sec.}\right)$.

BIBLIOGRAPHY.

Robert Sabine: "On the Measurement of very small Intervals of Time." *Telegraphic Journal,* May 15, 1876, vol. iv, No. 79, pp. 141–143. "A Method of Measuring very small intervals of Time." *Phil. Mag.*, ser. 5, May, 1876, vol. i, pp. 337–346.

H. R. Kempe: "Handbook of Electrical Testing," 1887, 4th ed, p. 329.

Mascart and Joubert: "Electricity and Magnetism," 1888, vol. ii, p. 282.

Devaux-Charbonnel: "Measurement of very short Time Intervals." *Comptes rendus,* May 14, 1906, 142, pp. 1080–1082. Science Abstracts (Physics), 1448 of 1906. *L'Electricien,* June 23, 1906, vol. xxxi, pp. 386–389.

B. O. Peirce: "Length of Time of Contact of a Quick Tap on a Telegraphic Key." *Proc. Am. Academy Arts and Sciences,* June, 1906, vol. xlii, No. 4, pp. 95–100.

Advantages of Abandoning All Guages. G. E. GODDARD. (*Amer. Mach.,* xxxiv, 400.)—Mr. Goddard in a thoughtful and clearly reasoned article points out the confusion and trouble arising from the numerous guages now used as standards, *e.g. Roebling's, Stub's* wire guage, the *B. W. G.,* the *Brown and Sharpe,* the *U. S. Standard,* the *Morse* steel wire, and the *British* steel wire guages; and suggests instead of these different guages the use of *decimal measurements only.* This action has been already recommended by two national societies, the American Society of Mechanical Engineers, and the American Railway Master Mechanics Association. Such a course as the adoption of one, and only one, standard guage would save much time and money and avoid numerous misunderstandings and consequent errors and delays.

ELECTRIC TRANSIENTS.

BY

DR. CHARLES PROTEUS STEINMETZ.

1. WITH the increasing size and importance of electrical systems, those phenomena, which temporarily occur in all electrical circuits, as oscillations, surges, electrical impulses and travelling waves, are becoming of increasing frequency and destructiveness, and a knowledge and understanding of their general nature and characteristics, and the cause of their origin, has become important and necessary for the electrical engineer.

While the theory of these electrical transients is still far from complete, and involves considerable mathematics, it is possible to gain an insight into their cause and origin, their nature and general characteristics, and even their most important numerical relations, without theoretical mathematics, and in view of the great and rapidly increasing importance of these phenomena, in the following an attempt is made to give without the use of mathematics a general discussion of them, and their bearing on the operation of electrical systems.

2. In general, an electric circuit comprises a source or generator, a line and a load. In the generator, electric power is produced from some other form of power, as mechanical, and flows over the line into the load where it is used. Not all the electric power produced by the generator reaches the load, but a part is consumed throughout the entire circuit, dissipated as heat by the resistance of the conductor: ri^2.

This however does not yet constitute the entire phenomena which we will call the flow of electric power, but there also is something going on in the space outside of the conductor which directs the flow of electric power: there is a *magnetic field*, lines of magnetic force encircle the conductor; and there also is an *electrostatic* or *dielectric field*, lines of electrostatic or dielectric force radiate from the conductor, and the magnetic field, and the electrostatic or dielectric field in the space outside of the conductor are just as essential parts of the flow of the electric power, as the power dissipation in the resistance of the conductor.

The magnetic field is proportional to the current i, with a proportionality factor which is called the *inductance* L of the circuit, and thus is Li; the dielectric field is proportional to the voltage e, with a proportionality factor which is called the *capacity* C of the circuit, and thus is Ce.

The magnetic field and the dielectric field represent *stored energy*: the energy stored by the magnetic field is

$$\frac{Li^2}{2},$$

and that stored by the dielectric field is

$$\frac{Ce^2}{2}.$$

Before a steady current can flow in a circuit, energy must therefore be supplied in producing its magnetic field; before a steady voltage can be on the conductor, energy must be supplied in producing its dielectric field. This energy is supplied by a flow of power from the conductor into the surrounding space in which the field exists. As the magnetic field is proportional to the current, the power required to supply its energy is given by a voltage, the *inductance voltage;* as the dielectric field is proportional to the voltage, the power required to supply its energy is given by a current, the capacity current, and inductance voltage and capacity current thus are the phenomena, by which the stored energy of the magnetic and dielectric fieds respectively is supplied to the space surrounding the conductors.

Whenever a change occurs in an electric circuit, which involves an increase of its stored magnetic or dielectric energy, as an increase of current or of voltage, power flows from the circuit into the surrounding space, until the stored energy has been supplied, and inversely, whenever a change occurs, which requires a decrease of the stored energy, power flows back from space into the circuit. This power flow is temporary, lasts only until the required stored energy has been supplied, or the surplus stored energy returned to the circuit, and thus it is called a *transient*.

Transients therefore are the phenomena, by which at a change of circuit condition the stored energy readjusts itself to the changed condition, and any change in an electric circuit, which requires a change of the stored energy, cannot occur instantly, but a transition period of the readjustment of the stored energy intervenes, before stationary conditions are reached, whether in a direct or alternating current circuit.

3. It is obvious, that transients are not a specifically electrical phenomenon, but occur in any system of forces, where energy storage occurs. Thus in a water power, energy is stored in the momentum

$$\frac{mv^2}{2}$$

of the moving mass of water in the supply pipe, etc., and any change of load, which requires a change of the flow of water and therefore of its stored energy, cannot be accomplished instantly, but a mechanical transient appears, and the problem of governing water powers, especially at high heads, is essentially the problem of taking care of the mechanical transient. In railroading, the periods of acceleration and of deceleration are nothing but the mechanical transients of the stored energy; the firing up and the cooling down of a steam boiler are thermal transients, etc.

In the preceding cases, energy is stored in one form only; as kinetic mechanical energy in the pipe line and the railway train, as heat energy in the steam boiler, and the only change of the stored energy, which can occur, is an increase or a decrease. If, however, energy is stored in two or more forms, in addition to the increase or decrease of stored energy, a transformation of stored energy from one form to another may occur, and usually does occur. This for instance is the case in the pendulum. When the weight of the pendulum comes to rest, in its end position, it contains stored potential energy of gravitation, due to its elevation above the lowest position. When the weight reaches the lowest position, all this potential energy has vanished; some has been dissipated by friction, but most converted into kinetic energy of motion, and the weight now contains stored kinetic energy. During its further motion, this kinetic energy is again converted into potential energy, until the weight comes to rest in the next end position, and so on, and gradually, by a series of periodic transformations between potential energy of elevation and kinetic energy of motion, the stored energy of the pendulum is dissipated.

Two classes of transients thus exist: single energy transients, in which energy is stored in one form only, and the phenomenon is a steady increase or decrease of the stored energy, and double energy (or multiple energy) transients, in which in addition to an increase or decrease of the stored energy, a transformation of stored energy between its two forms occurs, which usually is periodic.

4. In electric distribution circuits of 110 to 220 volts, in 600 volt railway circuits, and even in 2200 volt primary distribution circuits, the delectric energy

$$\frac{Ce^2}{2}$$

is still so very small compared with the magnetic energy

$$\frac{Li^2}{2},$$

that the former can be neglected compared with the latter (except under special conditions, as with lightning discharges, etc.) and the circuit can be considered as storing energy in one form only, as magnetic energy. The transients of such circuits thus are single energy transients, that is, a steady increase or decrease of the stored magnetic energy during the transition period after a circuit change. The dielectric energy becomes comparable in magnitude with the magnetic energy, in transmission lines of 30,000 volts and over, and in underground cables of 10,000 volts and over, and such high voltage circuits then give double energy transients, that is, surges of the stored energy. This is the reason for the appearance in high voltage circuits, of electrical disturbances different from those met in low and medium voltage circuits.

The single energy transients of electric circuits, which result from the stored magnetic energy, are rarely of serious importance: as they are a gradual change from the previous to the after conditions of the electric circuit, their inductive effects are usually small; due to the limited extension of such low and medium voltage circuits, their energy is moderate, and due to the relatively large resistance of most such circuits, the energy is rapidly dissipated, that is, the duration of the transient short, and they usually require consideration only to avoid the annoyance which may be caused by them. For instance, when closing the field exciting circuit of a shunt motor, an appreciable time—frequently several seconds—elapses before the magnetic field has built up, and if then the armature is energized immediately and the armature rheostat cut out too rapidly, momentarily a big current may flow through the armature, without starting it, as the magnetic field is not yet there, and this current rush may blow the fuses.

Of serious moment such magnetic single energy transients become when of abnormally great energy, that is, in very extended systems or in highly inductive circuits, as motor fields, and especially, when forced to be of very short duration, as in the latter case, even with a moderate amount of energy, the power may be very great, since it is the energy divided by the time in which it is dissipated. The latter is the case with the opening transient of an inductive circuit. In opening an inductive circuit its stored magnetic energy must be dissipated. If then an inductive circuit were opened instantly, that is, its stored energy dissipated in an infinitely short time, this would represent infinite power, that is, infinite induced voltage, or in other words, the insulation of the circuit would be punctured. To a considerable extent, an inductive circuit protects itself against too rapid opening, by the arc following the switch blades: the more rapid the switch opens, the greater is the induced voltage, and the further the arc follows and maintains the circuit, that is, limits the rapidity of the circuit opening. The problem of switching inductive circuits thus is, to open the circuit sufficiently rapid to limit the burning of the switch contacts by the arc, but to open sufficiently slow to limit the induced voltage below the value which would seriously endanger the insulation. Inversely, if an inductive circuit is opened very rapidly, as by a powerful air-blast across the opening switch, or a small condenser shunted across the break, practically unlimited voltages are produced, as in the Ruhmkorff coil.

5. Occasionally magnetic transients are of importance not directly by their stored energy, but by the power production which they cause. A characteristic instance hereof is found in the momentary short circuit currents of alternators. The voltage of an alternator depends on the field excitation and the load, that is, the magnetizing or demagnetizing action of the armature current, which combines with the magnetomotive force of the field excit-

ing current to a resultant, and the latter produces the magnetic field flux. At open circuit, the magnetic field flux is that due to the field excitation alone. If now with the same field excitation, current is drawn from the armature, especially if it is a lagging current, the demagnetizing action of this current lowers the field flux and with it the voltage. At short circuit, the armature current—which then is lagging—rises to such a value, that its demagnetizing action lowers the field flux to a small fraction of the value which would exist with the same field excitation at open circuit: The value just sufficient to circulate the short circuit current in the armature. With modern high speed turbo alternators, the permanent short circuit current may be about 4 times full load current, and the field flux at short circuit may be as low as one-tenth of the field flux, which exists at open circuit with the same field excitation. In short circuiting the alternator, the field magnetic flux thus decreases to one-tenth its initial value. As it represents stored energy, it cannot do so instantly, but can decrease only gradually—though rapidly—from open circuit to short circuit value, and in the first moment after short circuit it thus still has practically full open circuit value, that is, a value, which may be ten times as great as the permanent short circuit value. As the latter gives a short circuit current in the armature equal to 4 times full load current, the former gives ten times as high a current, that is, a momentary short circuit current which may be as high as 40 times full load value. Thus, the effect of the magnetic field transient of the alternator is an excessive transient current rush in the armature at short circuit. Considering, that the permanent short circuit current of the armature, of 4 times full load value, demagnetizes the field so as to drop it to one-tenth of its value, the momentary short circuit current, of 40 times full load value, would demagnetize 10 times as much, and as at this moment of the beginning short circuit the field flux still has full value, the field current also must momentarily increase to 10 times its normal value, to maintain full field flux against the excessive demagnetizing action of the momentary short circuit current of the armature. That is, the magnetic field at the moment of short circuit begins to decrease at such a rate that by its decrease it induces in the field exciting winding an e.m.f., which raises the field current to the value required to hold the field flux against the armature reaction. Thus the momentary current rush in the armature at short circuit, is accompanied by a corresponding current rush in the field. With single phase short circuit, this field current is pulsating with double frequency, as the single phase armature reaction pulsates with double frequency; with polyphase short circuit, a transient full frequency pulsation appears in the field current rush, corresponding to the starting transient of the armature current.

6. The most important, because most dangerous electrical transients are the double energy transients of high voltage circuits. In these circuits, in which the stored dielectric energy

$$\frac{Ce^2}{2}$$

is of the same magnitude with the stored magnetic energy

$$\frac{Li^2}{2},$$

the gradual increase of the total stored energy, at a change of circuit conditions, is accompanied by a surge, or transformation of the stored energy between its two different forms, similar as was illustrated on the pendulum as a surge between potential energy of gravitation, and kinetic energy of motion.

During the periodic transformation between magnetic and dielectric stored energy, the magnetic energy is a maximum,

$$\frac{Li_0^2}{2},$$

and therefore the oscillating current i a maximum i_0, at that moment, where all the energy is magnetic, that is, the dielectric energy

$$\frac{Ce^2}{2}$$

and therefore the oscillating voltage e is zero. The dielectric energy is a maximum,

$$\frac{Ce_0^2}{2},$$

and therefore the oscillating voltage e a maximum e_0, when during the periodic transfer of stored energy all the energy has become dielectric, that is, the magnetic energy

$$\frac{Li^2}{2}$$

and therefore the oscillating current i is zero.

It is however the same amount of stored energy (neglecting the gradual and slow decrease of energy by the power dissipation), which at one moment appears as magnetic, at the next moment as dielectric energy. That is, it is:

$$\frac{Li_0^2}{2} = \frac{Ce_0^2}{2}.$$

This *relation between the maximum value of the oscillating current, i_0, and the maximum value of the oscillating voltage, e_0,* is of the greatest industrial importance. It applies to all double energy transients, that is, surges of stored energy. Transposed, it gives:

$$\frac{e_0}{i_0} = \sqrt{\frac{L}{C}}$$

$\sqrt{\frac{L}{C}}$ is of the nature of an impedance, and is called the *natural impedance of the circuit,* and may be denoted by z_0:

$$z_0 = \sqrt{\frac{L}{C}}$$

in transmission lines, z_0 usually is between 200 and 600 ohms; it is must lower in cables, due to their high capacity C and low inductance L, and it is much higher in coiled circuits, as the high potential windings of high voltage transformers.

The great industrial importance of this relation between the maximum oscillating voltage and the maximum oscillating current is, that it allows the calculation of the one from the other. In most cases of electric surges of energy, one of the two quantities, the current or the voltage, is known, or can be estimated approximately, from the cause of the disturbance, and above relation allows the calculation of the other.

7. Consider for instance the switching on of a transmission line of 30,000 volts. With the switches open, the voltage on the line is zero; with the switches closed, the voltage has an effective value of 30,000, and thus a maximum value of $30,000 \sqrt{2} = 42,400$ volts. That is, at the moment of closing the circuit, a sudden change of voltage occurs on the line which as maximum can amount to: $e_0 = 42,400$.

If then the natural impedance of the line, as calculated from the equations or from the tables of L and C of line conductors is: $z_0 = 400$ ohms, the maximum oscillating current, which can be produced in the line by the operation of switching the dead line onto the live transformer is limited to:

$$i_0 = \frac{e_0}{z_0}$$

$$= \frac{42{,}400}{400}$$

$$= 106 \text{ amperes.}$$

Inversely, when a line carrying 30,000 volts is suddenly grounded, or short circuited, that is, its voltage changed from 30,000 volts effective, to zero, 106 amperes is the maximum current oscillation which may occur, and which, in case of short circuit, superimposes on the wave of the permanent short circuit current.

An interesting application of this relation is for the calculation of the maximum *lightning discharge* from a transmission line, against which the stations have to be protected. While the voltage of lightning may be practically unlimited, the maximum voltage which lightning can produce on the line obviously is limited by the disruptive strength of the line insulation against momentary voltages. If a higher voltage is impressed on the line by a lightning stroke (as frequently the case), it spills over at the next insulator, and if of sufficient energy, may puncture insulators, shatter cross arms and poles locally on the line, but the lightning discharge current, which rushes along the line towards the station, obviously is limited to the voltage which can actually exist, at least momentarily, on the line as result of the lightning stroke.

Assuming a 30,000 volt line: the insulators must be expected to stand continuously double voltage, or 60,000, and momentarily at least twice as much, or 120,000 to 150,000. Thus the lightning discharge current is limited to that given by the oscillating voltage of a maximum: $e_0 = 150{,}000$.

At a natural impedance of the line, of $z_0 = 400$ ohms, this gives:

$$i_0 = \frac{e_0}{z_0} = 375 \text{ amperes.}$$

Thus, 375 amperes is the maximum discharge current, which lightning could produce in this line, and thus the maximum current, against which the lightning arresters in the station have to protect in case of a lightning stroke on the line near a station. If the lightning strikes at a considerable distance from the station, obviously the discharge current at the station is much less, as the energy of the oscillation is rapidly dissipated in its passage along the line.

Allowing a momentary rise of voltage at the station of 50 per cent., the maximum voltage drop across the lightning arresters should be limited to half the maximum line voltage, or 21,400 volts. At 375 amperes discharge, this allows an impedance of the lightning arrester and its discharge path, of

$$z = \frac{21,400}{375} = 57 \text{ ohms.}$$

To afford effective lightning protection, the resistance of the lightning arrester and impedance of its connection to line and ground should therefore not exceed 57 ohms in this case.

If however the natural impedance z_0 were much lower, due to the use of large conductors and relatively short distances between the conductors, for instance, $z_0 = 200$, and two parallel lines led from the station, then, if both lines were struck simultaneously, the natural impedance of the discharge would only be:

$$\frac{z_0}{2} = 100 \text{ ohms,}$$

and the maximum discharge current thus 1500 amperes, and thus would limit the permissable impedance of the lightning arrester circuit to 14 ohms. That is, either a very low resistance arrester and very low impedance discharge path becomes necessary, or the use of several lightning arresters and several line and ground connections in multiple, to afford protection.

8. As seen, without going into detail study of the lightning transients, considerable information can be derived from the above fundamental relation of current and voltage of the double energy transient.

Inversely, this relation may be applied to determine the oscillating voltage, which may be produced by a sudden change of current in the line. Assuming that the full load current of the 30,000 volts line is 200 amperes effective, that is, has a maximum value of $200\sqrt{2} = 283$ amperes. If then, in switching off full load, the circuit would be broken at the maximum value of the current, the oscillation, which results, would be that due to a sudden change of current from 283 amperes to zero, that is:

$$i_0 = 283 \text{ amperes.}$$

At a natural impedance of: $z_0 = 400$ ohms, this gives a maximum oscillating voltage of:

$$\begin{aligned} e_0 &= i_0 z_0 \\ &= 283 \times 400 \\ &= 113{,}000 \text{ volts.} \end{aligned}$$

This is more than double voltage, that is, more than the voltage which the line can stand continuously, and already a moderate overload, as 50 per cent. would give an oscillating voltage higher than which the line could stand even momentarily, that is, would cause a flashover or a puncture of insulation.

Switching at or near maximum current thus is dangerous and frequently destructive, and the problem of controlling transmission lines is to devise a switching mechanism, which can be relied upon always to open the circuit at zero current. This is the reason which has lead to the development of the modern oil circuit breaker, as this type has the characteristic to open the circuit at the zero value of the current. It also has led to the abandonment of all types of air circuit breakers as dangerous on high voltage circuits, since the air circuit breaker cannot be relied upon to open always at zero current, but occasionally opens at or near maximum current, and then is liable to be destructive to the circuit insulation. The operation of the present extended high voltage systems thus has became possible only by the development of the modern oil circuit breaker.

As already the opening of full load current, when taking place at the wrong point of the wave, leads to dangerous voltages, it is interesting to see, what would be the result of opening a *short circuit* at or near maximum current.

Assuming the line impedance to be 20 per cent. at full load. That is, at full load current, the impedance voltage of the line is 20 per cent or one-fifth of impressed voltage. At short circuit, the total impressed voltage is consumed by the line impedance, and the short circuit current thus would be 5 times full load current, provided that the generating system can maintain full voltage on the line at least momentarily, in case of short circuit at the end of the line. With a full load current of 200 amperes effective or 283 amperes maximum, the maximum short circuit current would thus be 5 x 283 = 1415 amperes, and if interrupted at the maximum value, would give an oscillation of maximum current: $i_0 = 1415$ amperes, thus, with a natural impedance of the line of $z_0 = 400$ ohms, on oscillating voltage of maximum value:

$$\begin{aligned} e_0 &= i_0 z_0 \\ &= 1415 \times 400 \\ &= 566{,}000 \text{ volts,} \end{aligned}$$

that is, far beyond the possible insulation strength of the line, or in other words, the line insulation, no matter how good, would be broken down in case of a short circuit being interrupted at or near the maximum value of current.

The most destructive transient of a high voltage circuit thus is the short circuit oscillation.

Occasional short circuits however are unavoidable in transmission lines, either due to accidents in apparatus, or due to flashovers on the line, at defective insulators, by atmospheric electrical disturbances, by heavy winds swinging the wires together, etc. As far as the short circuits are opened by the oil circuit breakers in the system, they are relatively harmless, due to the nature of the oil circuit breaker to open at zero current. More dangerous are flashovers on the line, resulting in flaring arcs, which lengthen and then blow themselves out. Fortunately, such flaring arcs only occasionally develop their destructive possibilities, but usually go out at the zero of the current wave: at the end of one half wave, the arc vapor stream cools sufficiently so that at the beginning of the next half wave the arc does not start again. Occasionally however such arcs blow themselves out explosively, by the rapid expansion of the air due to the heat of the arc, and as the heating effect is a maximum at or near maximum current, this explosive rupture of a flaring arc tends to occur near maximum current, and then produces a destructive oscillation. Especially is this the case in low reactance high capacity circuits, as cables, where the current and therefore the heating effect in the flaring arc is very large and the arc inherently more unstable. Such flaring arcs thus constitute the most dangerous and destructive phenomenon of high voltage circuits.

It is interesting to note, that the surges resulting from a current transient are usually much greater in magnitude and thus in destructiveness, than those resulting from a voltage transient.

9. We have seen that in the surge of stored magnetic and dielectric energy, the current is a maximum when the voltage is zero, and inversely, that is, the oscillating current and the oscillating voltage are in quadrature, and the power thus is reactive, that is, surges to and fro, but there is no flow of power along the circuit. Such a surge of energy is called a *stationary oscillation, standing wave,* or *surge.*

Oscillating current and voltage may also be in phase with each other. Then there is a flow of power along the circuit, and the phenomenon is called a *travelling wave,* or an electric *impulse.* Travelling waves of high frequency frequently precede standing waves. Travelling waves have been observed of frequencies from a few hundred cycles, to millions of cycles; the former by oscillograph, the latter by spark gap across a small reactance.

In circuits comprising sections of different character, as transmission line, transformer, load, etc., that is, in most industrially important cases, the energy surge is a combination of standing waves and travelling waves. The energy surge obviously must die down simultaneously in all circuit sections. In some circuit sections however, as the transmission line, energy dissipation occurs at a greater rate than in other circuit sections, as transformer coils, and left separate, the surge would die down in the line much more rapidly than in the transformer. Thus, when line and transformer are connected together energy must be supplied to the line, from the stored energy of the transformer, by a travelling wave. Thus in the energy surge, or the transient of such a compound circuit, a flow of oscillating power occurs between the circuit sections. This results in a transformation of the oscillating voltage and current at the transition point between the successive circuit sections.

For instance, if a travelling wave passes from a transmission line into the high potential winding of the step-down transformer, and e_1 is the maximum voltage, i_1 the maximum current hence

$$p_1 = \frac{e_1 i_1}{2}$$

the power of the wave in the transmission line, e_2 the maximum voltage and i_2 the maximum current hence

$$p_2 = \frac{e_2 i_2}{2}$$

the power of the wave in the transformer; as the same power leaves the line which enters the transformer, it must be

$$\frac{e_1 i_1}{2} = \frac{e_2 i_2}{2}$$

e and i are however related by the natural impedance of the circuit section, that is:

$$\left.\begin{aligned} i_1 &= \frac{e_1}{z_1} \\ i_2 &= \frac{e_2}{z_2} \end{aligned}\right\} \qquad (2)$$

where z_1 is the natural impedance of the line, and z_2 the natural impedance of the transformer,

Substituting (2) in (1) gives:

$$\frac{e_2}{e_1} = \sqrt{\frac{z_2}{z_1}}$$

That is, *at the transition point between two circuit sections, a transformation of voltage occurs, with a transformation ratio, which is the square root of the ratio of the natural impedances of the two circuit sections, and a transformation of currents by the inverse ratio:*

$$\frac{i_2}{i_1} = \sqrt{\frac{z_1}{z_3}}.$$

This relation between the oscillating voltages and currents in different circuit sections is of fundamental importance in tracing their origin and destructiveness.

Hence, a travelling wave, coming from one circuit section into another circuit section of higher natural impedance, increases in voltage and thereby in destructiveness, and inversely, when entering a section of lower natural impedance, it decreases in voltage.

Thus, if a travelling wave of $e_1 = 30{,}000$ volts comes from a line of natural impedance $z_1 = 400$ ohms, into the high potential winding of a transformer, of natural impedance $z_2 = 3600$ ohms, it rises in voltage to:

$$e_2 = e_1\sqrt{\frac{z_2}{z_1}}$$

$$= 30{,}000\sqrt{\frac{3600}{400}}$$

$$= 90{,}000 \text{ volts.}$$

10. Electrical disturbances, originating in one circuit section, frequently develop their destructiveness in adjacent circuit sections, in which due to the higher natural impedance of the latter section they have risen to destructive voltages. The result, and the indication of a transmission line disturbance thus often is the break down of the transformers connected to the line, not because the transformers are weaker in insulation, but because the disturbance, while of harmless voltage in the line, has in entering the transformer risen in voltage to destructive values.

When speaking of voltage transformation at the transition point between two circuit sections, it is obvious that at the transition point the voltage is the same in both circuits, but a change of phase occurs, which results in a different maximum voltage some distance further on in the circuit, at the point where the voltage maximum occurs. With a voltage increase, this maximum is approximately a quarter wave distant from the transition point, and depending on the frequency of the wave, this point may be very near the transition point, with very high frequency waves, or far distant, with lower frequencies. Thus transformers may break down in the middle of their winding, as result of disturbances in the transmission line to which they are connected, if the disturbance is of moderate frequency, while the break down would occur in the end turns, if the disturbance in the line is of very high frequency. That is, the location of a break down in a transformer does not indicate, whether the disturbance originated in the transformer, or entered from the outside.

To conclude then, the two most important numerical relations, which govern the electrical disturbances in high voltage systems, are:

a. The relation between the maximum current i_0 and the maximum voltage e_0 of the oscillation, standing wave, impulse or travelling wave:

$$\frac{e_0}{i_0} = z_0$$

where:

$$z_0 = \sqrt{\frac{L}{C}}$$

is the natural impedance of the circuit.

b. The transformation ratio of voltages e_1 and e_2, and currents i_1 and i_2, at the transition point between two adjoining circuit sections, of the natural impedances z_1 and z_2 respectively:

$$\frac{e_2}{e_1} = \sqrt{\frac{z_2}{z_1}} = \frac{i_1}{i_2}$$

and from these two relations, very considerable information on the nature, cause and effect of transients can be derived.

"Brown" Gold or "Dark" Gold. M. HANRIOT. (*Compt. rend.*, clii, 138.)—"Dark" or "brown" gold is the name given by the author to the very finely divided gold obtained by the action of an acid on an alloy of gold and silver. When exposed to heat the color changes and it shrinks considerably. The shrinkage is slow and reaches its limit at the end of 5 to 6 hours. The shrinkage of the sheet, when exposed to nitric acid, depends only on the composition of the alloy and not on the temperature. The thickness has no effect, except that the thicker the sheet the longer it must be heated with nitric acid to completely remove the silver.

New American Lathes. ANON. (*Iron Age*, lxxxvii, 546.)—The American Tool Works Co., Cincinnati, O., have introduced two new types of high-duty lathes, said to be the latest and highest developed types, and to surpass in power, range, and convenience any previously designed lathes of similar sizes. Full descriptions and drawings are given in this article, which will repay those interested for its perusal.

ELECTRIC FURNACES.*

BY

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Consulting Electrical Engineer.

(SYNOPSIS.—The paper described the fundamental principles of the design, construction and operation of electric furnaces, their characteristics and idiosyncrasies, the characteristic differences between them and combustion furnaces, their relative advantages and disadvantages, etc., and was illustrated with a large number of lantern slides showing the construction of those in use, accompanied by statistical data concerning their outputs. As the discussion following the paper was confined chiefly to the writer's new type of furnace, additional data concerning it has been included in this abstract, by request.)

THE electric furnace is to-day no longer a laboratory device; it has taken a prominent place in the industries and has become a very important commercial apparatus, its importance growing daily. Not including the very large number of small laboratory furnaces, there are to-day hundreds of large furnaces in use in the industries producing thousands of tons of commercial products daily. In some cases the products are produced better or cheaper than before, while in others important products, which had never before been known or which could not have been produced with other furnaces, are now produced in large quantities.

Among the present uses of the electric furnace may be mentioned the refining of steel, the reduction of iron ores by means of water power, the production of aluminum, silicon, graphite, carborundum, alundum, calcium carbide, other carbides, bisulphide of carbon, ferro alloys, fused jewels, etc.

The electric furnace even promises to affect the wealth of nations. Sweden, one of whose national products for many generations was the famous Swedish iron, has for some time past been losing this important industry owing to the greatly increased cost of charcoal. But owing to the enormous water powers in that country, and the generous and wise aid of its parental government in developing them, Sweden will now be able to again recover that important national industry by means of the electric furnace, which requires only a fraction of the charcoal that the blast furnace does, and which enables the iron to be converted directly into refined steel of considerably higher money value.

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* Abstract of a paper presented at the meeting of the Electrical Section held Thursday, April 20, 1911.

Norway's national industries will no doubt also be affected by the electric furnace. Its barren rocky western coast, unfit for most other purposes, is admirably adapted for electric furnace industries, on account of its numerous easily available and nearly constant water powers located on the immediate coast where the products and raw materials can be cheaply shipped by water, which shipping will probably forever be open to normal competition and beyond the control of railroads, hence can always be relied upon to remain reasonable.

Canada and the states along the Pacific coast, which abound in water powers and mines but have no cheap coal, will no doubt also be greatly benefited by the electric furnace for reducing and refining the metals, provided nature's generous gift of water power will not be allowed to become monopolized by private interests, whose charges for power are governed only by the rule to charge " the highest price that the traffic can bear." The developments of the electric furnace industry will depend greatly on whether or not the governments can keep control of the water powers and regulate the charges. Existing power plants would no doubt find it profitable to encourage the use of their power for furnaces, by offering reasonable and attractive rates, with an assurance of their permanency.

In its general principle, the electric furnace is an extremely simple device, as it merely converts the most available form of energy, namely, electric energy, into the lowest and most degenerate form, heat. Nature tends to do this for us if we give her the opportunity. Hence so far as this conversion of electric energy into heat is concerned, electric furnaces require no skill to design; it is the reverse operation, namely, the conversion of heat into electrical energy, that is difficult and requires the highest skill of the engineer in the designing of boilers, engines and dynamos, each of which itself is the result of a vast amount of study and skill.

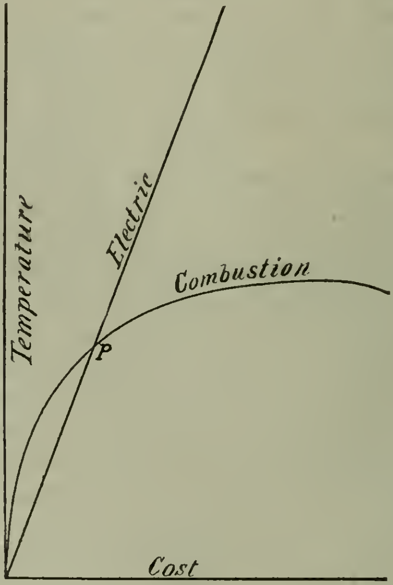
The engineering skill required in the design and construction of electric furnaces therefore lies not in the fundamental conversion of energy, but in building them well and efficiently, the latter being of far greater importance than in combustion furnaces in which the cost of a unit of heat is so much less that great economy is not of so much importance. Heat generated electrically costs more per unit of heat, hence to successfully compete with combustion heat it must have other advantages; one of these is that such heat can be applied more directly to the materials, hence with far less waste, and when in addition the furnace is built so as to keep the heat in it as much as possible, the difference in the amount of heat required may become very great, thereby compensating for the higher cost per unit.

A comparison of the costs of electric and fuel heat depends so largely on local conditions, that a general comparison would not be of much value. But there are certain important characteristic differences between the two which can be compared in a general way, and a comparison of these is quite instructive. It may be best shown by means of those useful tools called "curves," the international short hand language of engineers.

In the accompanying diagram, Fig. 1, let the horizontal distances represent costs and the vertical ones temperatures, and let the curves represent the costs of heating a given body, say a ton of steel, to the various temperatures, neglecting such modifying factors as latent heats and variations in the specific heats. The general shapes of the curves for the combustion heat and the electric heat will be roughly about as shown. For the combustion heat the costs for the lower temperatures will be seen to be quite small, but as the temperatures become high the costs increase very much more rapidly, so much so that the curve finally becomes horizontal and even falls again, hence has a maximum point. Beyond this point the volume of gases in the blast becomes so great that they carry off the heat more rapidly than the fuel can supply it, hence they actually reduce the temperature by chilling the fuel or the gases. A simple example of such a case is blowing out a candle, in which operation the too great volume of air carries off the heat more rapidly than the combustion can supply it, hence it chills the oil and the combustion consequently ceases. In all combustion furnaces the gases must necessarily leave at least at the temperature of the body which is heated, and generally they leave at a far higher temperature, and all the heat carried off by them is waste, except when it is partially recovered by regenerators. Another reason for such a maximum temperature is the dissociation of the gases, which means that the components cease to combine, hence cease to generate heat.

The corresponding curve for electric heat is roughly a straight inclined line, as shown; in other words, the cost increases at an approximately constant rate, and there is no maximum point, as long as there exists a material to carry the current. The two curves therefore always intersect each other, and at this point P the costs are equal.

FIG. 1.



It will readily be seen therefore that low temperature heat is in general generated more cheaply by combustion, while for the higher temperature heat it is cheaper to use electricity; also that for temperatures above the point P the cheapest way would be to combine the two, using combustion heat for the lower temperatures, below this point of intersection, that is, for melting or preheating cold charges, and electric heat for the higher temperatures, above the point *P*. This is what is now common practice in the electric steel industry, in which the melting is done by combustion heat, the hot metal being then run into the electric furnace for further treatment. If it were possible to so construct an electric furnace that both kinds of heat can be applied in the same furnace, then the advantages and the economy of this ideal combination could be fully realized. Such a furnace will be described below.

The relations of these two curves will, of course, vary with local conditions, and their shapes will also change somewhat; they should therefore be considered as showing only the general characteristics. Where water power is cheap and fuel expensive, the straight line will be steeper and the other one will rise less steeply and be more flat at the top, while in localities where there is no water power, and where coal is cheap, the curved line will rise more steeply.

The maximum temperature for the combustion curve in commercial furnaces is in the neighborhood of those used in the iron industry, roughly between about 1500° to 1900° C. (2700° to 3400° F.). The maximum for the electric arc furnace with carbon electrodes is their volatilization point, about 3500° to 4000° C. (6000° to 7000° F.), or just about double, hence far greater than necessary for most metallurgical purposes.

The chief advantages of electric furnaces over those of the combustion type are too well known to require more than mention here. They include the neutral atmosphere, that is, the heat is neither oxidizing nor reducing; the possibilities and ease of obtaining the higher temperatures; the rapidity of heating; metallurgical cleanliness (that is, no impurities like ash, sulphur, etc., introduced by the heating process); no losses in waste gases; greater possible economy in the heat losses; the heat may be generated in the material itself (in resistance as distinguished from arc furnaces); the heat may be generated at the bottom instead of at the top, at least in some resistance furnaces; ease, accuracy and reliability of control and regulation; greater uniformity and reliability of product; greater output for a given size of furnace or a smaller furnace for a given output; reduction of labor and sometimes of the plant; incidental advantages such as better castings due to greater fluidity of metal, less waste of metal, etc.

The purpose of furnaces may for convenience be divided into three general groups, although these often overlap. In the first group the chief purpose is merely to melt, vaporize, dry, etc., that is, to merely change the physical state, as for instance in the simple melting furnaces, the steam boiler, the drying furnaces, etc.; this is the chief field for the combustion furnaces.

In the second group the chief purpose is merely to provide a high temperature atmosphere so as to enable certain desired chemical reactions to take place which will take place only at those temperatures; little or no heat is actually consumed in these (except that to raise the cold materials to those temperatures), hence the only heat necessary to provide continuously is that required to supply the losses through the walls, chimney, electrodes, doors, etc., hence in these the reduction of the losses is of prime importance; to this group belong those for refining steel, making carborundum and graphite, glazing pottery, baking stonewares, the kitchen stove, etc.

In the third group the chief function is to store up chemical energy in the product, that is, to produce endothermic chemical reactions; in these, energy must be supplied not only to provide for a high temperature atmosphere, as in the second group, but also to provide that energy which is being stored chemically in the product and which in some cases may be the greater amount; the energy so stored cannot be counted upon to produce heat for raising or maintaining temperatures. To this group belong the furnaces for the reduction of metals from their ores, like iron, aluminum, zinc, silicon, etc., the production of calcium carbide, bisulphide of carbon, etc. All such elements or compounds may subsequently be used (generally by burning) to generate heat, light or other forms of energy (such as the electric energy from zinc in batteries), and it is the energy thus obtained that was stored in them in the furnace in which they were originally produced. In the designing of such furnaces it is therefore very important to know whether the product is endothermic, and to what extent, for unless the furnace is made to supply the energy which is to be stored in the compound it will be a failure.

As temperatures rise, the chemical affinities or bonds between the various elements become weaker and weaker until finally they cease to exist; when water, for instance, is heated to a high enough temperature, the oxygen and hydrogen composing it will exist free and uncombined as elements, as their bond has been broken; the water is then said to have been dissociated. When our earth was a mass of molten and gaseous material at extremely high temperatures, the various elements composing it were presumably in this uncombined form or at least in loosely combined compounds. As it cooled, the elements combined or mated in various forms, depending upon chance, that is, on the local supply. These bonds tightened as the earth cooled, and with the aid, later on, of the chemistry of plant life, the rock, water, and air composing the earth's outer envelope, were formed.

The electric arc furnace, apparently for the first time during those millions of years, enables us now to reproduce the extremely hight temperatures of those earlier periods, hence to again break most and probably all of those chemical bonds, that is, to unmate the elements, and by then providing proper artificial surroundings we are enabled to compel them to recombine or remate differently or remain uncombined, in accordance with our desires, hence improving on nature's process which depended upon chance. Iron, aluminum, silicon, zinc, lead, and other reduced metals, which nature has not given us as metals in the rock, are produced in this way, though not necessarily always in the electric furnace.

In general, electric furnaces may for convenience be divided into two types called resistance and arc furnaces, although the distinction is somewhat artificial. In the resistance type the heat is generated by passing the electric current through a solid or liquid conductor, the resistance of which causes the electric energy to be converted into heat. In the arc furnaces this resisting conductor is a gas, namely, the vapor of the electrode material, and as gases ordinarily have a very high specific resistance an arc furnace may be said to be a resistance furnace in which a very high resistance capable of carrying a very large current is confined in a very small space, hence the high temperatures.

In the arc the current forms its own conductor by vaporizing the end of the electrode. Hence its temperature is always that of the boiling point of the electrode material; if it were momentarily any higher it would vaporize more material and this would reduce it again. This temperature therefore seems to be a fixed one, but it is generally far higher than what is wanted for most operations. It seems to be the limit which can be reached in an arc furnace, but being almost always so much higher than is needed, it seldom if ever acts as a limitation to a process.

This extremely high temperature is the chief advantage of the arc furnace; it is reached instantaneously in the arc itself.

By far the greater part of the total heat is believed to be generated in the arc and at the end of the electrode, only a smaller part being set free in the furnace product itself which generally forms the other electrode; hence the larger part of the heat has to be transmitted to the material by radiation and by whatever convection there may be due to the hot vapors coming into contact with the material; in both these mehods of heat transmission, however, the speed of transmission increases with the temperature of the generated heat, and this speed is a very important element in furnace design. This is the redeeming feature in that high temperature, as in other respects it is very objectionable, because it increases the losses very greatly; in an ideal furnace the temperature should not be higher than needed, on account of this increased loss. In some cases this locally high temperature of the arc produces injurious results on the product and is therefore objectionable, and sometimes even fatal; in melting brass, for instance, there is danger in volatilizing some of the zinc.

The energy consumed in vaporizing the electrodes cannot, of course, appear as heat also, hence it represents a constant loss unless it is again recovered by subsequent condensation or burning, in which case, however, it becomes useful only if the recovered energy actually reaches the product.

As carbon or graphite electrodes are usually used in arc furnaces, the vapor is that of carbon, which presumably acts reducingly, and is known to tend to form carbides with the materials. The advantages of metallic electrodes to reduce the electrode losses cannot be made use of in arc furnaces. Another disadvantage is that in heating liquids with the arc (and everything seems to melt in the arc), the heating must necessarily be from the top only, hence the transmission of the heat from the lower terminal of the arc to the rest of the material must be by the slow process of conduction, except in so far as agitation may distribute it by convection. It is evidently wrong in principle to heat a liquid from the top, as it is then necessarily a slow process; this is therefore an intrinsic disadvantage of the arc furnace, but is partly compensated by the extremely high temperatures which tend to hasten such transmission of heat. The mechanism required for regulation, the constant attention required by such regulators, and the breaking off of the ends of the electrodes, are further objectionable features of arc furnaces. These objectionable and undesirable features are, however, often outweighed by the advantages, as such arc furnaces have become very important in the industries and have produced excellent and valuable results.

Resistance furnaces have other advantages and disadvantages. When the resistance conductor, usually called the resistor, is a solid, there seems to be no limit to the temperatures that can be produced in it, as long as the material remains a solid. This is the case in the carborundum and graphite furnaces in which exceedingly high temperatures are generated. This seems to apply also to those resistance furnaces in which the heat is generated in a solid resistor, as for instance in a bed of coke or in blocks of carbon, and is then radiated to the material to be treated. In the latter case, however, the temperature of the furnace products must necessarily be considerably lower or else no heat would reach them, and the speed of heating depends on the rapidity at which the heat can be radiated across the intervening space.

When the material through which the current passes is a liquid in an open channel, there is a very decided limit to the temperature that can be produced, and it is sometimes a seriously low one. This is due to the fact that there is a limit to the current which can be passed through a horizontal open channel containing a liquid, for when the current reaches a certain amount, depending on the cross section and shape of the column and on the specific gravity of the liquid, the column is suddenly contracted by electromagnetic forces until it breaks the circuit; this produces rapid interruptions of the current, which prevent a further increase of current and are fatal to the operation of the furnace. This curious electromagnetic phenomenon was described by the writer some years ago[1] and was named the "pinch phenomenon," by which it is now generally known.

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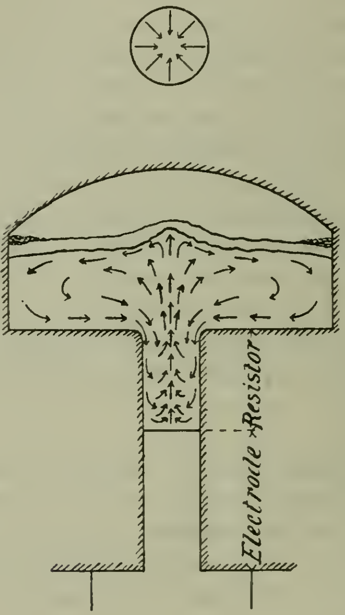
[1] "A Practical Limitation of Resistance Furnaces: The 'Pinch' Phenomenon," *Trans. Amer. Electrochem. Soc.*, 1907, vol. xi, p. 329. "The Working Limit in Electrical Furnaces Due to the 'Pinch' Phenomenon," *Trans. Amer. Electrochem. Soc.*, 1909, vol. xv, p. 255.

Were it not for this phenomenon, the resistance furnace would approach the ideal in some respects for liquids because the heat is generated in the material itself, as it is in the graphite furnaces, hence the utilization of the heat is complete, that is, 100 per cent., which means that the only losses of heat are those from the charge, as distinguished from those which never reach the charge.

FIG. 2.



In an endeavor to overcome this serious limit in liquid resistance furnaces imposed by this pinch effect, the writer has devised a form of furnace in which this obstructing force not only cannot sever the conductor, but is even made to produce a very valuable property, namely, rapid circulation of the liquid in the resistor and in the hearth. The principle is shown in Fig. 2.

If a column of a liquid conductor is confined in a vertical cylindrical hole in the bottom of the hearth, opening into the body of the liquid and closed at the bottom by means of the electrode, and if a current be then passed lengthwise through it, the effect of the pinch phenomenon will be to contract this column toward its central axis; the liquid will therefore tend to move radially from the circumference to the centre, as shown in the small circle at the top of Fig. 2. These forces in turn, by hydraulic action, then produce an axial force which will force the liquid upward and out of the column, while at the same time the suction will draw in fresh liquid around the circumference, producing a circulation about as shown by the arrows in the lower figure. This peculiar phenomenon acts like a valveless pump, forcing the liquid upward and producing a small fountain.

These liquid columns or resistors, of which there are two, one for each electrode, are so proportioned that the whole heat for the furnace is generated in them, and the diameter and current are so proportioned that the pinching force is sufficient to produce the desired circulation. Each particle of the liquid in turn enters the resistor, where it is immediately highly heated and ejected, being in the resistor only about a second. The freshly heated metal is forced to the top where, in the case of steel refining, it comes into intimate contact with the blanket of slag where the chemical action which constitutes the refining, takes place. The cooler material at the bottom flows into the resistor and is in turn heated and ejected. For three-phase current there are three resistors and electrodes.

Among the advantages claimed are: quick action, which means a large output per day and less standby losses per ton; a very large effective surface of contact with the slag, as this surface is continually being renewed, hence rapid refining action; rapid purification of suspended matter (slag, gases, oxides, etc.), as this is freed as the liquid reaches the top and deposits such matter in the slag; heating from the bottom, which is the more rational method; practically perfect homogeneity, on account of the rapid and systematic circulation; possibility of making the hearth deep and narrow instead of shallow and broad, hence reducing the rather large losses through the walls; reduction of the temperature to the lowest necessary for the chemical reaction, that is, no excess of temperature with its attending increase of the losses; the possibility of using metal electrodes, which are much more economical in losses of power than those of carbon or graphite; no consumption of electrodes, which is such an important item of cost in arc furnaces; no contamination of the material with that of the electrode, as the latter is made of the same material; no continual adjustment of the electrodes as in arc furnaces, and therefore no expensive machinery for doing it; ease and nicety of regulation by merely varying the voltage of the transformer; capability of adding fuel heat at the top in the form of gases for preheating the cold material and producing the low temperature heat, thereby obtaining increased economy, as was described above; as the current is generated in a separate transformer, there is no reduction in the power factor; the larger the furnace the better does the principle apply; the possibility of applying it to exsting open hearth furnaces; simplicity and compactness of construction; ease of operation; ease of making repairs of the tubes; etc.

Figs. 3 and 4 show in its outlines only, a small, crude form of crucible tilting furnace of this type. The sketches are self explanatory. It is shown as tilting around the lip, so as to pour directly into moulds. It is started either with a small liquid charge, just enough to connect the ends of the electrodes when tilted; or by melting a small charge in it with an oil flame; or by a casting made to fit the bottom and then melted electrically; a small charge is always left in it and this can readily be melted with the current when it may have become frozen.

FIG. 3.

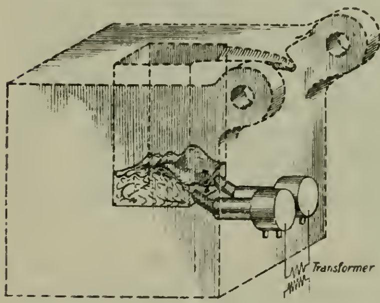
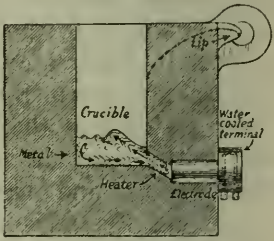


FIG. 4.



Figs. 5 and 6 show how these resistors or squirting tubes and their electrodes may be applied to the usual type of tilting furnace. Fig. 5 is a vertical section through one of the two electrodes and tubes; Fig. 6 shows a top view of a horizontal section at about the level of the doors.

Another form of liquid resistance furnace, which was originally intended to dispense entirely with the electrodes and their troubles, is known as the induction furnace. The liquid is in a narrow circular channel which forms the secondary circuit of a transformer, hence the current is induced in it without the necessity of electrodes. It is so well known, having been invented about twenty-five years ago, that a further description need not be given here. (Numerous forms of it were shown among the lantern slides.) It has come into use in Germany chiefly for steel refining, and its introduction seems to be increasing; it is not yet in use to any extent in this country. It posses the advantages which liquid resistor furnaces have over arc furnaces, as mentioned above. It is started with a liquid charge or a ring of cold metal. It is significant that in its most successful form electrodes are introduced to heat a larger open part of the bath necessary for operating the slags and for adding cold scrap or pigs. Its disadvantage, besides its cost, is that the frequency of the alternating current must be quite low or else the power factor becomes very low. This means larger machinery, though not necessarily more power. This disadvantage increases with the size of the furnace. The pinch effect would probably also limit the rapidity of action, by limiting the current which can be passed through the metal. It is difficult to provide for good heat insulation on account of the very large surface of metal exposed to the walls.

FIG. 5.

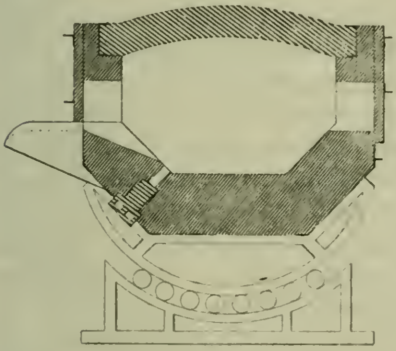
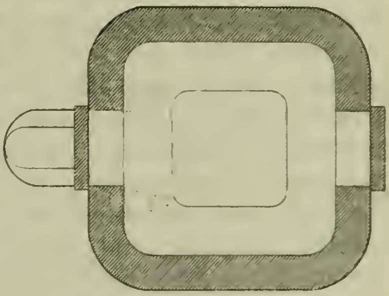


FIG. 6.



One of the chief features in the work of the engineer, in the designing of electric furnaces, is the reduction of the losses of heat, that is, the increase of the heat efficiency of the furnace; electric heat being much more expensive than heat from fuel, the only way it can be expected to compete successfully, as far as the cost of the heat is concerned, is by the best possible utilization of the energy; it is possible to control the losses to a far greater degree in electric than in combustion furnaces. The practice in the heat insulation of combustion furnaces would be quite inadequate for well built electric furnaces.

The reduction of the heat losses in electric furnaces, which have no chimney losses, involves the flow of heat through solids, a subject which until recently has not been given the attention which its importance demands. Heat insulation is rendered more difficult by the fact that nature has given us no virtually perfect heat insulators like those for electricity, and that even if they existed they could not be used for high temperature insulation on the outside of a furnace, as the whole furnace wall would then assume the full inside temperature, like in cases of over-insulation, which few known refractory materials would stand; and if used on the inside of a furnace it would have to withstand the chemical actions of the liquid materials and slags. Apparently the only way a high temperature furnace can be insulated effectively with present materials is to provide for a certain allowable flow of heat through the walls, which shall be as small as possible, but not so small as to run the risk of over-insulation, which is more serious than insufficient insulation, as the walls and roof are then destroyed. It therefore requires careful designing, and there is great need of data which at present exists either only in very crude form or not at all.

There are two kinds of losses of heat from the interior of an electric furnace, namely, those through the walls and through the electrodes, which are subject to the control of the designer, assuming, of course, that the doors and openings of other kinds are made as few and small as possible. A few years ago the writer made analytical studies of these two sources of losses, some of the conclusions of which were quite surprising, showing that former practice had been in some respects far from correct. The chief results are briefly as follows:

The usual formulas used for calculating the thermal resistance of such bodies as the walls of furnaces were found to be very greatly in error, as much as 100 per cent. and over, for thick walls. In general, for a flaring conductor, like one of the thick walls of a rectangular furnace, the proper mean cross section is not the arithmetic mean between those at the two ends, but the geometric mean, that is, the square root of their product.

Using the strictly correct formulas, it was found that the losses diminished very rapidly at first as the walls are increased in thickness, but that after the thickness has been increased to about one-half or three-fourths of the inside diameter, any further improvement in reducing the losses becomes small. The space in the inside of a furnace should be as small as possible to hold the charge, as the losses for the same charge increase rapidly with an increased inside surface. The losses in a large furnace can be made far smaller relatively to the charge than in smaller ones; hence it is considerably better to use one large furnace than two smaller ones of half the capacity.[2]

Concerning the losses in and through the electrodes, the problem was far more involved, and former practice was in some respects found to have been radically wrong. An electrode naturally should be a good electrical conductor in order to reduce the resistance losses. But it then also is a good heat conductor and therefore will tend to abstract considerable heat from the charge in the inside, thereby chilling it. Increasing its cross section decreases one of these losses and increases the other, thereby complicating matters. The results of the analysis are briefly that, by so proportioning an electrode that the current in it will heat its inner end to the furnace temperature, the total combined losses will be the least possible, and the electrode will at the same time abstract no heat from the charge; it will then in effect act as a perfect heat insulator, better even than the walls, as far as chilling the product is concerned.

Another result was that our former practice to base the size of electrodes on certain allowable current densities was found to be entirely wrong. Still another unexpected and surprising result was that graphite with its higher heat conductivity was more economical in size and losses than carbon, and that the metals were far better than either, the best electrode material being copper, quite the contrary to what would have been supposed. The accompanying illustration, Fig. 7, taken from one of the writer's papers, shows the relative sizes and losses when the electrodes for the same furnace are made of different materials.

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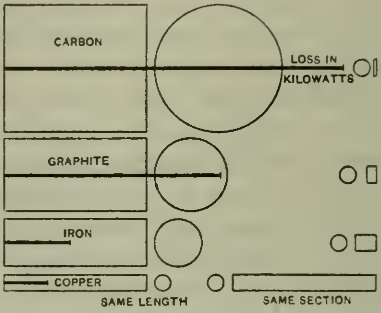
[2] For further deductions see the paper by the writer on "Heat Conductances Through Walls of Furnaces," *Trans. Amer. Electrochem. Soc.*, 1908, vol. xiv, p. 215.

It is a good illustration of the commercial value of an analytical research. As the physical constants for determining electrodes did not exist, the writer had to determine them by means of tests made under electrode conditions, whereby certain troublesome factors in the theoretical analysis become eliminated. The complete analysis, description of the tests, and the data for the calculation of electrodes are given in the original papers.[3]

In view of an article on "Simplicity in the Measures of Physical Quantities," published in the February issue of this JOURNAL, p. 129, in which the writer showed the advantages which would be gained by simplifying our units of measurement, it may be of interest to call attention here to the fact that such calculations of the flow of heat as those just referred to above become very greatly simplified, and in fact ideally simple, if the proper units are chosen. If in the present cases thermal resistances are used instead of conductivities, and if a new unit of resistance is adopted called the thermal ohm, calculations of the flow of heat, or of heat currents, become quite analogous and

FIG. 7.



Comparison of sizes and losses.

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[3] "Laws of Electrode Losses in Electric Furnaces," *Trans. Amer. Electrochem. Soc.*, 1909, vol. xvi, p. 265. "A New Method of Measuring Mean Thermal and Electrical Conductivities of Furnace Electrodes," *Trans. Amer. Electrochem. Soc.*, 1909, vol. xvi, p. 317. "The Proportioning of Electrodes for Furnaces," *Proc. Amer. Inst. Elec. Eng.*, March 31, 1910. "Determination of the Constants of Materials for Furnace Electrodes," *Trans. Amer. Electrochem. Soc.*, 1910, vol. xvii, p. 151. "Empirical Laws of Furnace Electrodes," *Trans. Amer. Electrochem. Soc.*, 1910, vol. xvii, p. 171. "The Design of Furnace Electrodes," *Elec. World*, June 16, 1910, vol. lv, p. 1598.

just as simple as those for electrical currents, as the coefficients are then unity.

This was explained in a recent article.[4] Briefly, if the currents of heat are represented in watts, instead of calories per second (which in itself saves a double transformation of units), the temperature in centigrade degrees, and the thermal resistances in those new units called thermal ohms, then, analogously to Ohm's law,

$$\text{watts} = \frac{\text{degrees}}{\text{thermal ohms}}$$

which is an ideally simple calculation. And if the specific thermal resistances of the various heat insulating materials are given in terms of these thermal ohms, which transformation is made once for all in preparing the tables, then as in electrical calculations, if r is this specific resistance of the material, R the total thermal resistance of a furnace wall or an electrode, S the cross-section of it perpendicular to the flow, and L the length parallel to the flow, then

$$R = \frac{rL}{S}$$

which is correct for centimetres or inches, provided the same units are used consistently throughout.

In conclusion, the following statistical data concerning existing commercial furnaces may be of interest.

The carborundum furnaces are 30 feet long and 12 feet wide, require 1600 kilowatts at 20,000 amperes, 80 volts and 25 cycles, have an estimated temperature of 2300° C., and yield 15,000 pounds of crystalline carborundum at each run.

The graphite furnaces are just like these and yield about 17 tons per day, the output last year being 12,000,000 pounds of a purity up to 99.9 per cent.; the temperature is estimated to be about 4000° C.

The silicon furnaces are double electrode arc furnaces 10 feet wide and 16 feet long, and require about 1000 kilowatts.

The bisulphide of carbon furnace is 41 feet high, 16 feet in diameter, requires about 400 horsepower, and yields about 6 tons per day; it is a three-phase arc furnace with three electrodes; the temperature is said to be about 1000 to 1500° C. Although built in the last century (1898) when it was probably by far the largest electric furnace ever constructed, it is running to-day as it was then. It is probably the most efficient electric furnace in use, as far as the economy of heat is concerned. It revolutionized the manufacture of bisulphide of carbon. The materials charged are sulphur and charcoal, and the product is a vapor which is subsequently condensed.

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[4] "Thermal Resistance and Conductance; the Thermal Ohm and Thermal Mho," *Met. and Chem. Eng.*, Jan., 1911, vol. ix, p. 13.

For the melting and refining of steel there seem to be at present nearly 100 arc furnaces in use mostly in France and Germany, although the few in this country include the largest ones. They are chiefly of the Heroult and the Girod types. They are mostly of about 300 to 800 kilowatts, and are for charges of 2 to 5 tons; the largest ones are in South Chicago and Worcester, having a capacity of 15 tons and requiring about 2000 kilowatts. There are also several ore reduction arc furnaces in use and under construction on the Pacific Coast, and in Domnarfvet, Sweden, the latter producing 2500 tons per year and requiring 400 kilowatts, or about 6500 pounds of pig-iron per horsepower per year. In Norway two furnaces are under construction, each for 7500 tons annually, requiring 1850 kilowatts.

The Government of Sweden is about to make available 600,000 horsepower, a large part of which will be used for reducing iron. Electric furnace reduction of iron is said to save about two-thirds of the carbon, only one ton of charcoal being used instead of three, per ton of iron. The escaping gas is three times richer as it contains no nitrogen, and is only one-eighth in amount, hence correspondingly less heat is carried off by it. Finely powdered ore can be used without briquetting; there is less labor cost and less cost of erection.

Of the induction furnaces there are between 30 and 40 in operation, mostly in Germany. They are mostly of 200 to 500 kilowatts; maximum 750. The charges are from 1½ to 5 tons; maximum 8½ tons. In some cases the material is charged hot and in others cold.

Among the pioneers in this country to whom the present commercial furnaces are due may be mentioned Acheson, Taylor, Hall, Tone, and Colby; and abroad, Heroult, Girod, Keller, Kjellin, and Stassano.

A NULL METHOD FOR MEASURING RELATIVE INTENSITIES OF RÖNTGEN RAYS.

BY

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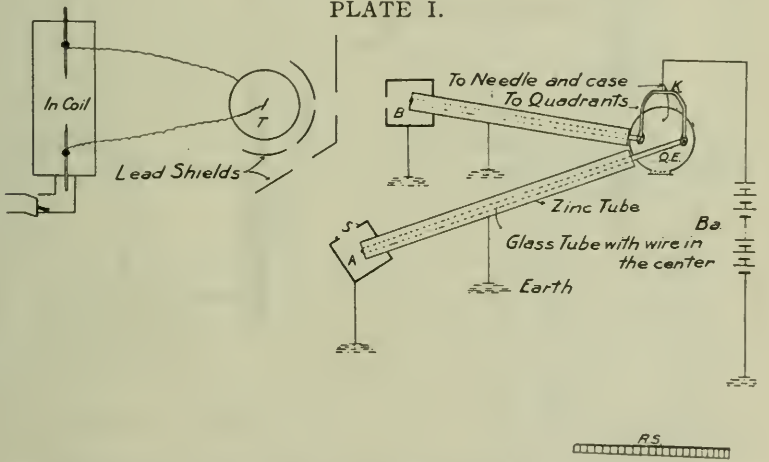
Department of Physics, Pennsylvania State College.

The method of measuring relative intensities of radiation of Röntgen rays by the discharge of electroscopes requires considerable time, not only in the actual reading, but also in the arrangement of the apparatus so as to eliminate as far as possible any leak in the systems. Furthermore, the readings extend over such long periods of time that errors may be introduced owing to changes in conditions, especially changes in potentials. Those who have had experience with this method have felt the need of greater accuracy and speed.

PLATE I.



In. coil, induction coil; *T*, X-ray tube; *S*, shutter; *B* and *A*, electroscopes; *QE*, quadrant electrometer; *K*, hinge switch; *Ba*, dry cells, 450 volts; *R S*, reading scale.

The work described in this paper investigates the two following hypotheses:

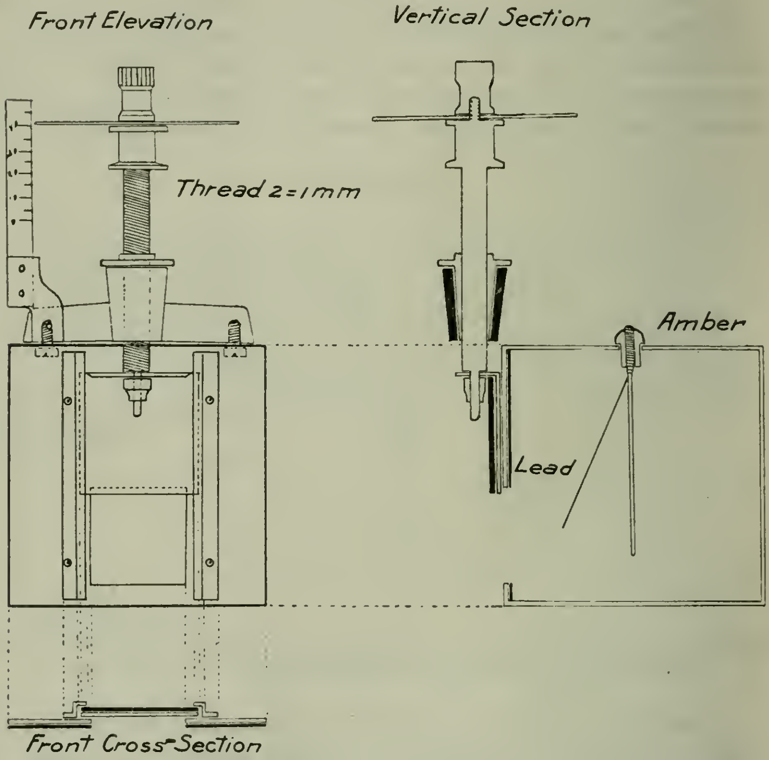
1. *The amount of ionization caused in an ionization chamber by rays emanating from the target of an X-ray tube varies inversely as the square of the distance of the chamber from the target, neglecting absorption.*

2. *The amount of ionization caused in an ionization chamber by Röntgen or other rays having ionizing power varies directly as the area of the opening allowing the rays to enter the chamber.*

Both hypotheses assume a point source.

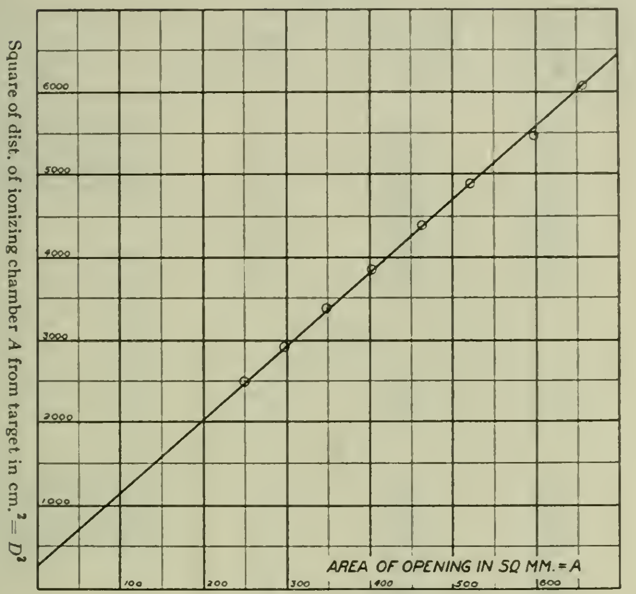
To these hypotheses may be added that the amount of ionization is proportional to the fall of the leaf in an electroscope (used as an ionization chamber in this case), provided the fall is small in comparison with the total deflection and provided change in capacity is negligible.

PLATE II.



The arrangement of apparatus for testing this method is shown in Plate I. Two similar electroscopes, arranged symmetrically with respect to the normal to the target of a Crookes' tube, served as ionization chambers. Chamber *A* was placed on a track so that its distance from the target could be varied at will, while chamber *B* remained at a fixed distance. Chamber *A*

PLOT I.



PLOT II.

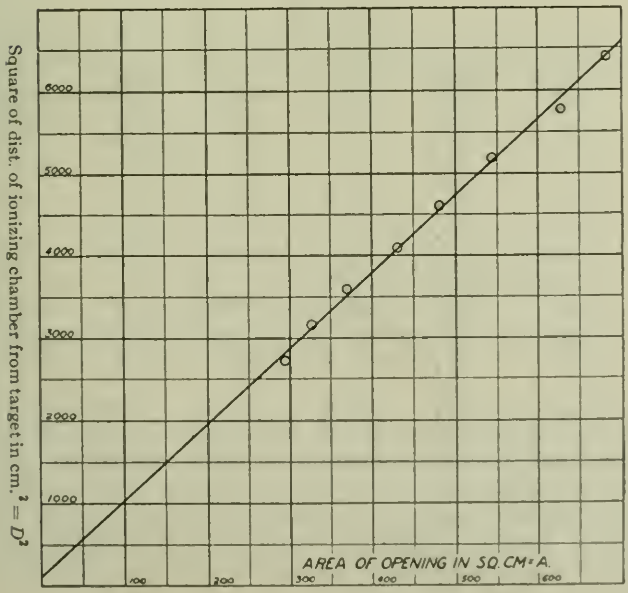


TABLE I.

Reading No.	Area of opening in *A*.	Sq. of distance from *T*. to *A*.	Distance from *T*. to *A*.	Remarks
1	666	6084	78	On account of the coef. of absorption of air, the area of opening in *A* has to be larger than it would be if this did not enter.
2	598	5476	74	
3	520	4900	70	
4	458	4356	66	
5	402	3844	62	
6	350	3364	58	
7	298	2916	54	
8	252	2500	50	

TABLE II.

Reading No.	Area of opening in *A*.	Sq. of distance from *T*. to *A*.	Distance from *T*. to *A*.	Remarks
1	682	6400	80	The result of the absorption of air entering, as mentioned above, is to bend the curve away from the origin. See Plots.
2	628	5776	76	
3	546	5184	72	
4	484	4624	68	
5	430	4096	64	
6	368	3600	60	
7	328	3136	36	
8	294	2704	52	

TABLE III.

Time in secs.	Readings electros *A*.	Readings electros *B*.	Corrected discharge of *A*.	Corrected discharge of *B*.	Ratio of discharges $A \div B$	Depth of opening in *A*.
47	94 33	90 15	54.8	71.6	0.762	2.0 mm.
32	97 24	74 15	68.8	56.8	1.211	4.0 mm.
24	94 18	60 10	72.2	47.9	1.509	6.0 mm.
18	100 18	55 9	79.6	44.7	1.781	10.0 mm.
13.2	99 18	45 5	79.3	39.0	2.029	14.0 mm.
11	100 22	44 5	86.5	38.2	2.266	18.0 mm.

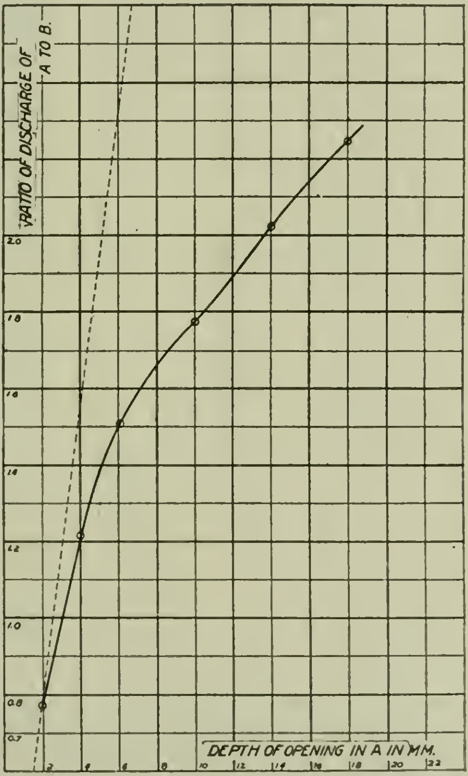
Natural rate of leak of electroscope $A = 0.1317$ divisions per sec.

Natural rate of leak of electroscope $B = 0.0717$ divisions per sec.

NOTE.—In the above the whole system was connected, but no attention was paid to the quadrant electrometer. The case was grounded, the quadrants connected to the electroscopes and charged; then the tube was run and the readings of the electroscopes taken.

was also provided with a shutter as shown in Plate II, which would measure depths to .005 millimetre, and as the area is directly proportional to the depth this depth was used, in plotting, as areas. Both chambers were connected directly to the quadrants of an electrometer; thus when the fall of potential in the two chambers was the same the needle remained at rest. These connections were made by means of fine wire enclosed in a glass tube, and this in turn was surrounded by a grounded zinc pipe, in order to do away with any changes in the capacity of the system.

PLOT III.



Readings with ionizing chambers connected to quadrant electrom. with case grounded and quadrants charged to 450 volts.

By placing *A* at a fixed distance from the target and varying the openings in its face until the ionizing effect in the two chambers was balanced, as shown by the electrometer needle, a series of readings were taken, keeping the opening in *B* constant.

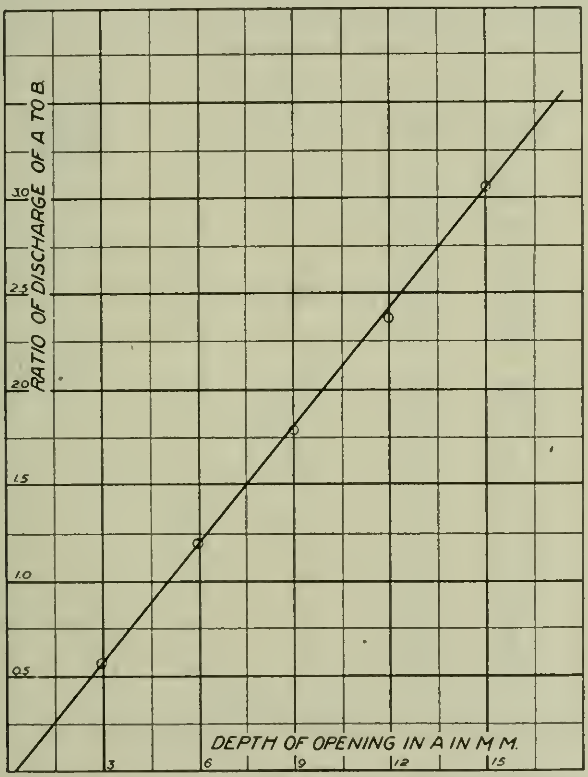
TABLE IV.

Time in secs.	Readings *A*.	Readings *B*.	Discharge of *A*.	Discharge of *B*.	Ratio of discharge $A \div B$, mean	Depth of opening in *A*.
12	66 21	95.5 17	45	78.5	0.573	3.0 mm.
12	65 22	96 17	43	75		
6	88 13	79 17	75	62	1.200	6.0 mm.
6	96 21	78 15	75	63		
4	95 18	59 16	77	43	1.778	9.0 mm.
4	100 17	64 17	83	47		
3	95 19	49 17	76	32	2.365	12.0 mm.
3	95 22	42 11	73	31		
2.4	94 19	40 15	75	25	2.980	15.0 mm.
2.4	90 18	40 15	74	25		

NOTE.—The natural leak was so small as to be negligible. The electroscopes alone were connected and readings taken as shown above. This is the ideal condition, as there is no needle to be changing the capacity of the system and no adjacent quadrants to leak. In Plot IV and in Plot V the curves pass through the origin. In the other cases shown the conditions are not ideal, therefore the results cannot be ideal. However, as is pointed out later, in the actual use of this method the conditions are ideal.

Table I shows the data thus taken, and if the two hypotheses are correct, the graph, using areas of opening in *A* as abscissas and the squares of distances of *A* from the target as ordinates, should be a straight line passing through the origin. Plot I does not quite fulfil this condition, but the difficulty was evidently due in part to the fact that some of the rays which entered the ionizing chamber came from the glass instead of the target. For, by shielding the tube with thick lead sheets, openings in which permitted only rays coming directly from the target to pass, most of the difficulty was overcome.

Plot IV.



Readings with everything but ground disconnected from ionizing chamber.

However, Table II and Plot II still show a tendency to turn away from the origin in a clockwise direction. This can be explained by the absorption of the air increasing with the distance of *A* from the target and thus reducing the intensity of the rays. Consequently, the opening in *A* for a given distance would have to be larger in order to balance with *B* than otherwise. For this reason we must modify hypothesis I by adding the clause: *provided the rays are travelling through a medium which exerts no appreciable absorption upon them.*

Thus far we have only shown the two hypotheses to be consistent with each other. It remains to be shown that they do not both involve the same errors and are consistent with the electroscope method. To do this, the method founded on the second hypothesis was checked by means of the discharge of electroscopes.

TABLE V.

Time secs.	Readings *A.*	Readings *B.*	Discharge of *A.*	Discharge of *B.*	Ratio of discharge *A.* ÷ *B.*, mean.	Depth of opening in *A.*
35	96 56	75 7	38	67	0.57	3.0 mm.
35	99 59	86 20	38	65		
35	100 27	92 31	71	60	1.16	6.0 mm.
35	100 19	94 24	79	69		
25	97 0	74 16	95	57	1.73	9.0 mm.
25	98 1	88 34	95	53		
15	100 15	87 52	84	35	2.24	12.0 mm.
15	98 21	91 58	76	33		
15	98 16	90 53	71	37		

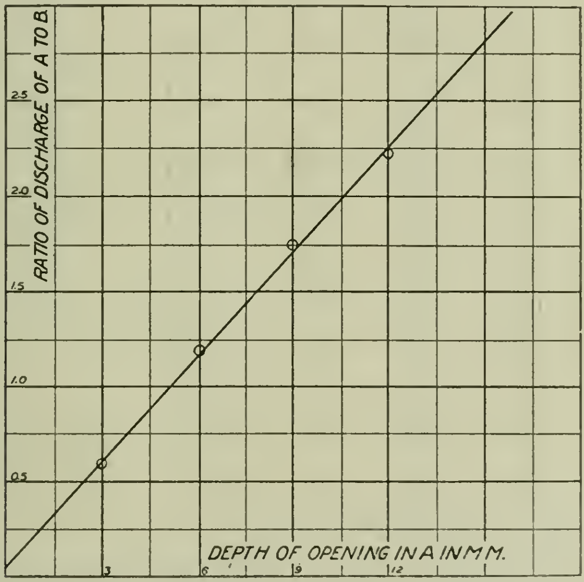
NOTE.—Connecting wires attached to electroscopes, but electrometer left out.

Natural rate of leak of electroscope $A = 0.063$ divisions per sec.
Natural rate of leak of electroscope $B = 0.023$ divisions per sec.

Micrometer microscopes were set up to take the ratios of discharge of the ionization chambers. Then by varying the opening in *A* a set of readings was taken as shown in Table III, Plot III. As the opening in B was kept constant the ratio of discharge of A to the discharge of B should vary directly as the area, or as the depth of opening of A. The results do not show this law, but as will be seen later the trouble was evidently due to leakage.

To find this trouble the ionization chambers were disconnected from everything but the ground and a series of readings taken as before. Table IV and Plot IV show the law of variation to be expected, *i.e.,* rate of discharge varies directly as the depth of opening of A.

PLOT V.



Readings with QE disconnected, but with all other connections intact.

Now the connecting tubes between the chambers and the electrometer were attached and another series of readings taken. The results shown in Table V and Plot V still conform with our reasoning. Therefore the trouble was not here.

There was but one thing remaining to be connected, namely, the electrometer. Hence the trouble must be here. The needle was first taken out and then the electrometer was connected and readings taken as before. Table VI and Plot VI, the results of this arrangement, do not fulfil the requirements. The nature of this inconsistency led to the belief that the trouble was due to a leak between quadrants. In order to lessen the chance of leak the opposite quadrants were disconnected, leaving only one quadrant on each ionization chamber. The data with this arrangement was consistent with the theory as appears from Table VII and Plot VII.

TABLE VI.

Time in secs.	Readings *A*.	Readings *B*.	Discharge of *A*.	Discharge of *B*.,	Ratio of discharge *A*. ÷ *B*., mean.	Depth of opening in *A*.
40	92 23	85 18	61.4	67.2	0.93	3.0 mm.
40	93 18	84 7	68.4	72.2		
30	92 5	85 23	81.3	58.4	1.48	6.0 mm.
30	93 7	86 26	80.3	56.4		
22	93 5	85 35	84.2	47.6	1.80	9.0 mm.
22	94 7	86 38	83.2	45.6		
18	95 8	86 45	84	39	2.15	12.0 mm.
18	92 5	85 44	84	39		

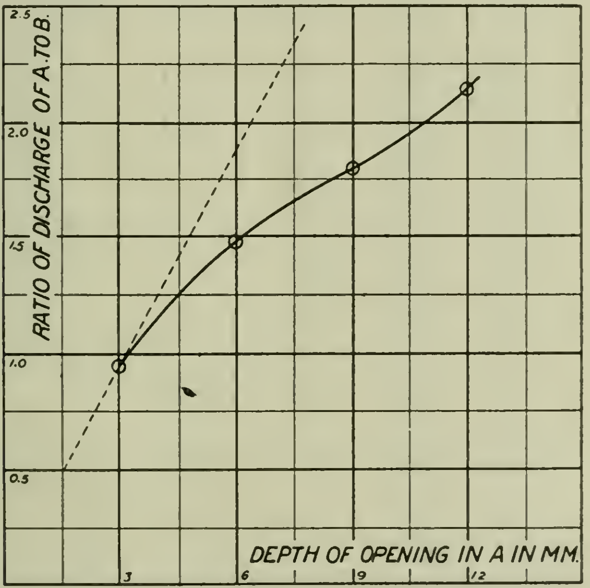
Natural rate of leak for 1st half of readings for $A = 0.19$ divisions per sec.
Natural rate of leak for 2nd half of readings for $A = 0.17$ divisions per sec.
Natural rate of leak for 1st half for $B = 0.12$ divisions per sec.
Natural rate of leak for 2nd half for $B = 0.11$ divisions per sec.

NOTE.—The needle was taken out and the electrometer connected. The curve does not pass through the origin and is not a straight line. The conditions are not ideal, as the quadrants are not at the same potential and the needle is not steady.

This seemed to locate the trouble as a leak from quadrant to quadrant, so the silk insulated wires which had connected the opposite quadrants were replaced by bare wires and the data for Table VIII and Plot VIII was taken. Evidently these results satisfy the theory.

The needle was now replaced and anchored in a fixed position so as to eliminate any chance of a change in the capacity of the systems due to a change in the position of the needle. The data of Table IX and Plot IX taken under these conditions still show some remaining difficulty although the plot is a straight line. However, it seemed probable that the remaining difficulty was such as to disappear under conditions which must exist in the actual use of the method. To test this reasoning a set of readings was taken under the ideal conditions of actual use, *i.e.*, by balancing the ionizing effect for each reading.

Plot VI.



Readings with both sets of quadrants connected, needle still out.

Since this is a null method, the quadrants were at the same potential and the needle in a fixed position when the area of opening was taken. Therefore, there was no tendency to leak from quadrant to quadrant and no change of capacity due to changes in the position of the needle. Furthermore, to do away with any chance of a leak to the ground, the case, the needle, and the quadrants were all charged to the same potential. The case and needle were connected to the battery throughout the test, thus causing a slight leak. However, this leak was determined and corrected for; besides, the two systems had practically the same capacity, so there is no appreciable error introduced if this correction is not applied.

TABLE VII.

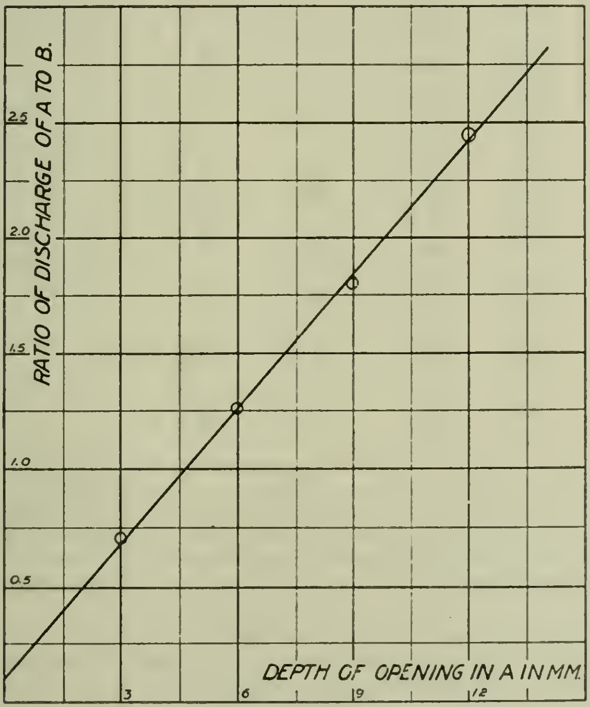
Time in secs.	Readings *A*.	Readings *B*.	Discharge of *A*.	Discharge of *B*.	Ratio of discharge *A*.÷*B*., mean.	Depth of opening in *A*.
40	93 38	87 13	49.0	69.3	0.707	3.0 mm.
40	93 38	87 13	49.0	69.3		
30	94 24	87 33	66	51	1.28	6.0 mm
	92 16	87 27	72	57		
30 22	95 20	87 45	72	39.7	1.82	9.0 mm.
	94 17	87 44	74	40.7		
22 17	95 5	87 49	87.7	36.3	2.46	12.0 mm.
17	94 6	87 51	85.7	34.3		

NOTE.—Connections the same as in Plot VI, excepting that one quadrant was connected to *A* and one to *B*. This tended to keep the leak from quadrant to quadrant down; the case was still grounded, however, giving an opportunity for a leak.

Natural rate of leak of $A = 0.150$.
Natural rate of leak of $B = 0.096$.

In proceeding with this arrangement a series of readings shown in Table X were taken. The area of opening of *B* was set at different values and the opening in *A* was varied until the electrometer needle was balanced. Then the rate of discharge of *A* should have the same ratio to the rate of discharge of *B* as the size of the opening of *A* has to that of *B*. Thus this ratio should remain a constant as the ionization effect is balanced each time. The results agree with this theory to within one place in 200. They were therefore taken as sufficient evidence that the theory and method are correct and valid.

PLOT VII.



Readings with only one set of quadrants, needle out.

In applying this method to the problems of relative intensities of Röntgen rays it is only necessary to measure the areas, as will be readily seen by applying it to the determination of the coefficient of absorption of metals. From hypothesis 2, the amount of ionization varies directly with the area of opening which permits the ionizing rays to enter the chamber. Also the amount of ionization is directly proportional to the intensity of the rays. Therefore, in order to get any desired amount of ionization, that is, in order to balance the ionization in *B*, we

TABLE VIII.

Time in secs.	Readings *A.*	Readings *B.*	Discharge of *A.*	Discharge of *B.*	Ratio of discharge *A.* ÷ *B.*, mean.	Depth of opening in *A.*
60	92 71	84 63	7	12	0.569	3.0 mm.
60	93 69	86 61	10	16		
60	94 56	86 57	24	20	1.205	6.0 mm.
60	93 50	86 53	29	24		
60	93 23	87 44	60	35	1.724	9.0 mm.
60	92 18	86 41	64	37		
60	94 2	86 40	82	38	2.14	12.0 mm.
60	94 0	86 38	84	40		

Natural rate of leak of $A = 0.23$ divisions per sec. for first four readings.
Natural rate of leak of $B = 0.15$ divisions per sec. for first four readings.
Natural rate of leak of $A = 0.167$ divisions per sec. for last four readings.
Natural rate of leak of $B = 0.133$ divisions per sec. for last four readings.

NOTE.—Connections the same as in Plot VI, excepting that the silk insulated wires that connected the quadrants were replaced by bare wires. Connections do not quite satisfy the ideal conditions yet, as the needle was not steady and the quadrants not at the same potential. However, most of the leak was done away with. The curve is a straight line, but it does not quite pass through the origin. As the conditions approach the ideal, the curve approaches the origin.

must open *A* an amount that will be inversely proportional to the intensity of the rays entering *A*. That is,

$$\frac{I_1}{I_0} = \frac{A_0}{A_1} \tag{1}$$

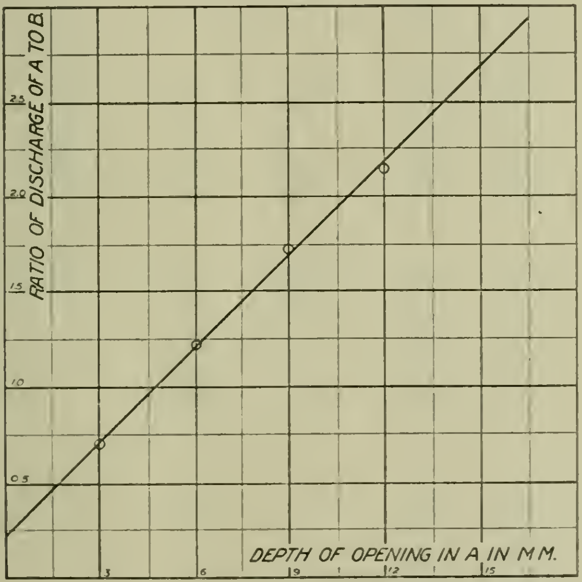
where I_1 and I_0 are the intensities of the rays with and without the absorbing substance in the path, and A_0 and A_1 are the corresponding areas of opening.

The formula for absorption is

$$I_1 = I_0\,\varepsilon^{-\lambda x}$$

where λ is the coefficient of absorption and x is the thickness of the absorbing substance.

PLOT VIII.



No needle in QE. Silk insulated wires replaced by bare wires.

Then,

$$\frac{I_1}{I_0} = \varepsilon^{-\lambda x}$$

or substituting the value for $\frac{I_1}{I_0}$ from equation (1) we have,

$$\frac{A_0}{A_1} = \varepsilon^{-\lambda x} \tag{2}$$

or

$$A_0 = A_1\varepsilon^{-\lambda x}$$

whence

$$\lambda = \frac{\log_\varepsilon A_1 - \log_\varepsilon A_0}{x}$$

TABLE IX.

Time in secs.	Readings *A*.	Readings *B*.	Discharge of *A*.	Discharge of *B*.	Ratio of discharge *A*. ÷ *B*., mean.	Depth of opening in *A*.
60	95 52	76 24	36.2	47	0.78	3.0 mm.
60	99 54	79 25	38.2	49		
60	88 41	73 17	40.2	51		
60	90 24	72 20	59.2	47	1.32	6.0 mm.
60	99 26	79 24	66.2	50		
60	90 13	74 14	70.2	55		
60	100 7	79 24	86.2	50	1.79	9.0 mm.
60	100 5	81 25	88.2	49		
40	91 19	74 34	67	36		
40	99 14	78 38	80	36	2.19	12.0 mm.
40	97 13	77 36	79	37		
40	92 1	73 30	86	39		

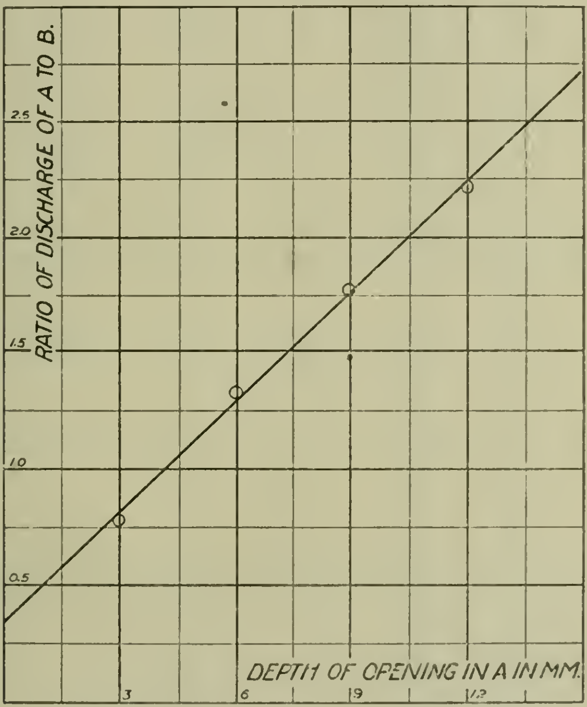
Natural rate of leak of $A = 0.113$.
Natural rate of leak of $B = 0.085$.

NOTE.—Connections same as in Plot VIII, but needle was anchored so as to keep it at a constant reading. However, the quadrants were not at the same potential and the case was still grounded. In the next Table, No. X, the conditions are made ideal, as when the apparatus is in use for actual measurements.

This method was used to measure the coefficient of absorption of chemically pure tin and the values shown in Table XI are of the same order of magnitude as those previously obtained by an electroscope method.* The potential, however, in the two cases was different so that no direct comparison can be made.

From the foregoing work the possibilities of this method are easily discernible, its ready adaptability to the various problems in relative intensity of Röntgen rays, the rapidity with which readings can be taken, the lessening of the chance for personal error, and the high degree of accuracy render it perhaps more desirable than the electroscope method. The difficulties of the scheme have been pointed out as fully as possible in order to aid others in adjusting the apparatus for the use of this method.

Plot IX.



Whole system connected, needle anchored at one position by a Pb anchor in the H_2SO_4.

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* See *Physical Review*, January, 1910.

TABLE X.

Time in secs.	Readings *A*.	Readings *B*.	Discharge of *A*.	Discharge of *B*.	Ratio of discharge *A*. ÷ *B*., mean.	Ratio of area *A*. ÷ *B*.
40	85 19	72 34	61	36	1.68	1.65
40	78 19	69 34	65	39		
40	78 14	70 30	65	38		
20	83 10	72 27	71.5	44	1.68	1.71
20	80 8	70 28	70.5	41		
20	81 7	70 27	72.5	42		
8	87 10	73 27	76	46	1.71	1.68
8	86 4	72 26	81	46		
10	82 4	71 26	77	45		
4	82 4	69 22	77.5	47	1.62	1.66
4	82 4	70 21	77.5	49		
4	79 2	69 22	76.5	47		
3	83 3	60 14	80	46	1.71	1.68
3	80 1	60 13	79	47		
3	82 1	60 13	80	47		
2	84 1	58 8	83	50	1.65	1.62
2	85 0	59 7	85	51		
2	85 0	59 5	85	52		

Natural rate of leak = 0.133 for *A* and 0.05 divisions per sec. for *B*. Notice that conditions are ideal and that results are ideal.

TABLE XI.

Reading No.	Depth of opening D_0	Depth of opening D_1	Thickness of tin sheets	Coef. of absorption λ
1	6.5	10.1	0.00126 cm.	343
2	6.6	10.2		
3	6.6	10.15		
4	6.6	14.7	0.00252 cm.	316
5	6.6	14.7		
6	6.6	18.7	0.00379 cm.	275
7	6.6	18.9		
8	6.6	24.0	0.00505 cm.	255
9	6.6	24.2		

The thickness of sheets was obtained by measuring its area, weighing it, and then applying the principle that area times thickness times density equal weight.

Formula for coefficient of absorption is

$$\lambda = \frac{\log_\epsilon D_1 - \log_\epsilon D_0}{x}.$$

Tin used was found by analysis to be practically pure.

Report of Progress on Flame Standards. E. B. ROSA and E. C. CRITTENDEN. (*Amer. Illum. Engin. Soc. Trans.*, v, 753.)—Treats of the merits and defects of the Hefner amylacetate lamp and the Harcourt 10 c.p. pentane lamp. Eight Hefner lamps are in use at the Bureau of Standards and the conclusion drawn from results with these is that the specifications are not sufficiently precise, and that some lamps slightly depart from the specifications. Of the two styles of light the Krüss alone is recommended. Many determinations of the humidity correction were made, and the result closely agrees with that of Liebenthal, who first determined this correction at the Reichsanstalt. As a standard for comparison they used a carbon filament lamp operated at about 9 watts per candle, which gives a color match with the Hefner. With regard to the pentane lamp a greater difference was found among different pentane lamps than among different Hefner lamps. It is known that this lamp increases in c.p. for some time after lighting, but no careful measurements have been made to show when a stationary value has been reached. The highest c.p. obtained from any pentane lamp tested at the Bureau is 9.9, while the lamp at the National Physical Laboratory is 10 c.p. The humidity correction is fully discussed, and the barometric pressure correction is stated to be about 0.6 per cent. for a change of 1 cm. in the pressure. It is considered that while the results so far obtained are encouraging, much remains to be done to make the pentane lamp a thoroughly satisfactory flame standard.

The Industrial Fixation of Atmospheric Nitrogen. E. LAMY. (*Met. Chem. Eng.*, ix, 99.)—According to Paul Lemétayer the Chile deposits still contain 240,000,000 tons of nitre, enough for over a century. These deposits cover an area 10,000 square miles. The recent improvements in coke oven practice has raised the total world's production of ammonium sulphate to 800,000 tons per year. Cyanamide when first manufactured was not well suited for agricultural purposes, as it was extremely caustic. This defect has been overcome by moistening and oiling the product before shipment; or the cyanamide powder is mixed with a proportion of iron oxide. The Birkeland and Eyde furnace is remarkably durable, and runs for a year on moderate repair charges; the refractories last 5 or 6 months, and the electrodes 3 to 4 weeks. The two largest of these furnaces have a capacity of 2940 k.w. The Badische Co. furnaces at present use only 700 to 800 k.w.; even then the arc is 22 feet long. The average production from both types of furnaces is nearly equal, about 13,000 pounds of nitric acid per k.w. year. In the Pauling process, at Roche-de-Rame, France, air is blown on a long electric arc. The resulting gas mixture contains 1.15 to 1.20 per cent. of nitrogen oxide at a temperature of 700°–750° C. This excess heat is used to pre-heat the air before it enters the furnace. The final product is sodium nitrate 97–98 per cent. pure. The efficiency of the Pauling furnace is about equal to that of the Birkeland and Eyde or the Badische furnaces. Pauling electrodes last 580 to 600 hours.

Decomposition of Water by Ultra-Violet Light. A. TIAN. (*Comptes rendus*, clii, 1072.)—Very exact observations have shown that under the influence of the radiations emitted from a mercury vapor lamp in quartz, water is decomposed into hydrogen and hydrogen peroxide; and the latter undergoes a further decomposition, yielding oxygen. The quantity of oxygen is however always less than the theoretical amount, but the loss decreases the longer the exposure is continued. This decrease leads to the conclusion that it is due to one of the two following reactions: (1) the inverse action of hydrogen dissolved in oxygenated water, or (2) the combination of hydrogen and oxygen. This latter reaction has been already noted between gaseous bodies at the end of a sufficient period of time the effect of the light is the same as that of electrolysis, with regard to the gases disengaged.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, June 21, 1911.*)

Hall of the Franklin Institute,
Philadelphia, June 21, 1911.

President Walton Clark *in the Chair.*

The minutes of the previous meeting were read and approved and the report of the Board of Managers transmitted by the Actuary was accepted and ordered filed.

As there was no communication to be presented and no unfinished business the meeting adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, June 7, 1911.*)

Hall of the Franklin Institute,
Philadelphia, May 3, 1911.

Dr. Geo. A. Hoadley *in the Chair.*

The following reports were presented for first reading:

No. 2353.—Poulsen's Telegraphone. Advisory. Adopted.

No. 2454.—Thayer's Dirigible Airship. Advisory. Adopted.

No. 2485.—Hixon's Electric Furnace for Smelting Zinc. Advisory. Adopted.

No. 2405.—Law's Universal Clock. Advisory. Adopted.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

Changes of Address.

Mr. Hiram W. Hixon, Worthington, Ontario, Canada.
Mr. Ralph D. Mershon, 65 West Fifty-fourth Street, New York City.
Mr. Jos. J. O'Brien, Room 18, Provident Bank Bldg., Washington, D. C.
Mr. George R. Wood, Olive Bldg., Pittsburg, Pa.
Mr. Wm. A. Haines, 1712 Green Street, Philadelphia, Pa.

NECROLOGY.

Mr. Edmund Richards Tatham, 1114 Spruce Street, Philadelphia. Born October 4, 1857, son of the late George N. Tatham; died June 19, 1911. He was an alumnus of the University of Pennsylvania and a life member of the Institute.

LIBRARY NOTES.

Purchases.

ROUSSET, J.—Les machines a ecrire.
CHURCH, A. E., AND G. M. BARTLETT.—Elements of Descriptive Geometry.
GARNETT, W. H. S.—Turbines.
American Society for Testing Materials. Memorial volume of Chas. Benjamin Dudley.
PERRIN, J.—Brownian Movement and Molecular Reality.
COLVIN, FRED H.—Machine Shop Mechanics.
ROE, J. W.—Steam Turbines.
KRAUS, E. H., AND W. F. HUNT.—Tables for the Determination of Minerals.
Aeronautical Classics, Nos. 1 to 5 inclusive.

Gifts.

Ontario Department of Agriculture, Forty-first Annual Report of the Entomological Society for 1910. Toronto, 1911. (From the Department.)
Great Britain Labour Department, Fourteenth Abstract of Labour Statistics, 1908–1909. London, 1911. (From the Labour Department.)
Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher, Abhandlungen Band 92–93; Leopoldina, 46 Heft, 1910. Halle, 1910. (From the Academy.)
New York Public Service Commission, Annual Report for 1909, vols. 1 to 3. Albany, 1910. (From the Commission.)
Musee Teyler Archives, ser. 2, vol. 12, part 2. Haarlem, 1911. (From the Museum.)
India Forest Administration, Review of, for 1908–09. Calcutta, 1910. (From the Supt. Government Printing Office.)
Vermont General Assembly, Acts and Resolves passed by the Twenty-first Biennial Session, 1910. Rutland, 1911. (From the State Library.)
Ontario Dairymen's Associations, Reports for 1910. Toronto, 1911. (From the Department of Agriculture.)
Oklahoma Geological Survey, Bulletin No. 2, Report on the Rock-Asphalt, Asphalite, Petroleum, and Natural Gas in Oklahoma. Norman, 1911. (From the Survey.)
University of Pennsylvania Engineering Alumni Society. Report of the First Annual Meeting held June 11, 1910. Philadelphia, 1911. (From the Society.)
K. K. Geographische Gesellschaft in Wien, Mitteilungen Band 53, 1910. Wien, 1910. (From the Society.)

City and Guilds of London Institute. Report of the Council, 1911. London, 1911. (From the Institute.)

International Mining Manual, 1911. Denver, n. d. (From Mr. James M. Swank.)

Massachusetts Board of Gas and Electric Light Commissioners, Twenty-sixth Annual Report, 1910. Boston, 1911. (From the Board.)

United States National Museum. Report for the year ending June 30, 1910. Washington, D. C., 1911. (From the Smithsonian Institution.)

BOOK NOTICES.

ELEMENTS OF DESCRIPTIVE GEOMETRY. With applications to Spherical and Isometric Projections, Shades, Shadows and Perspective. By Albert E. Church, LL.D., late Professor of Mathematics in the United States Military Academy, and George M. Bartlett, M.A., Instructor in Descriptive Geometry and Mechanism in the University of Michigan. 286 pages, 8½ x 5½ inches, cloth. Price, $2.25. American Book Company, New York, 1911.

The many friends which this book has made in its long service as a college text-book will be pleased to learn that it will not be suffered to go out of print, although it appears in a much changed form and now bears jointly the names of the original author and the present editor. As formerly published, the text and plates were in separate volumes. The present edition is in a single volume, the beautifully engraved plates having been replaced by well-executed line cuts interspersed in the text.

A few changes have been made in the order of presentation and other features have been introduced to bring it in harmony with present-day methods of teaching. The work, however, retains its former valuable features and in its new form may be expected to enjoy a renewed lease of life.

MEMORIAL VOLUME COMMEMORATIVE OF THE LIFE AND LIFE-WORK OF CHARLES BENJAMIN DUDLEY, PH.D., late president of the International Association for Testing Materials and of the American Society for Testing Materials, 269 pages, portraits, illustrations, 8vo. Philadelphia, American Society for Testing Materials, no date.

This memorial volume contains a series of interesting monographs, covering different phases of the life and career of Dr. Dudley.

The several articles were written by his intimate friends and associates, each selecting one particular topic, the whole illustrating the wide field of activity that came within the range of this many-sided man.

This book is prefaced with a touching poetic tribute from the pen of Dr. Harvey W. Wiley.

The labors of Dr. Dudley were so useful to the Corporation that he served, and incidentally to the whole scientific and industrial world, that the American Society for Testing Materials, whom he had served as President for many years—and who recognized him as their chief source of aid and inspiration—have performed a solemn duty by the preparation of this volume. Those interested in the life-work, as well as the amiable personality of Dr. Dudley, can procure copies of the book by addressing Prof. Edgar Marburg, Secretary American Society for Testing Materials, University of Penna., Philadelphia.

PUBLICATIONS RECEIVED.

Colorado School of Mines Magazine, vol. 1, Nos. 8, 9, May and June, 1911, 2 parts, illustrations, 8vo. Golden, Colorado.

U. S. Bureau of Mines. Technical paper No. 2. The escape of gas from coal. By Horace C. Porter and F. K. Ovitz. 14 pages, 8vo. Washington, Government Printing Office, 1911.

Automobile Club of America. Technical Committee. Facilities for tests and rules governing tests, together with information regarding the equipment installed in the testing laboratory at the club house. 32 pages, illustrations, 8vo. New York, 1911.

U. S. Department of Agriculture, Forest Service. Circular No. 175. The growth and management of Douglas fir in the Pacific Northwest. By Thornton T. Munger, Forest Assistant. 27 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

U. S. Coast and Geodetic Survey. Directions for magnetic measurements. By Daniel L. Hazard, computer, Division of Terrestrial Magnetism. 130 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

Scientific Study of the Criminal. By Arthur MacDonald, Washington, D. C. Reprint from the American Legal News (Detroit, Michigan), for May, 1911. 15 pages, 8vo.

U. S. Bureau of Mines. Technical paper No. 1. The sampling of coal in the mine. By Joseph A. Holmes. 18 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

North Carolina Geological and Economic Survey. Economic paper No. 21. Proceedings of the third annual drainage convention held at Wilmington, North Carolina, November 22 and 23, 1910, and North Carolina Drainage Law codified. Compiled by Joseph Hyde Pratt. 67 pages, plates, map, 8vo. Raleigh, State Printers, 1911.

U. S. Coast and Geodetic Survey. Results of observations made at the Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1907 and 1908. By Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 94 pages, plates, 4to. Washington, Government Printing Office, 1911.

U. S. War Department. Annual Reports, 1910. Containing reports of the Secretary of War, the Chief of Staff, the Adjutant-General, the Inspector-General, the Judge-Advocate-General, the Quartermaster-General, the Commissary-General, the Surgeon-General, the Paymaster-General, the Chief of Ordnance, the Chief Signal Officer, the Chief of Coast Artillery, Chief of Engineers (without appendices), the Departments, the Military Academy, Military Parks, Chief, Bureau of Insular Affairs, Philippine Commission, Acts of the Philippine Legislature, the Governor of Porto Rico. 4 vols., illustrations, plates. Washington, Government Printing Office, 1911.

CURRENT TOPICS.

New Telegraph Cable Between England and Norway. (*Elect. Eng.*, vii, 14.)—A new cable has been laid between Newbiggin in Northumberland, and Arendal in Norway. This is worked by the Great Northern Telegraph Co., for both governments in a circuit from Newcastle to Christiania. The total length is 411 nautical miles. For four nautical miles at the Arendal end the cable is double armored; 66 nautical miles are light deep sea cables, and 341 heavy deep sea cable. The insulation is of gutta-percha.

Sodium Nitrate Substituted for Iceland Spar. ANON. (*Ind. Chim.*, x, 330.)—Crystals of sodium nitrate have been exhibited recently at Paris, so pure and perfectly formed that they can be substituted for calcite in optical instruments. It is expected that these crystals can soon be furnished in such form as to meet all the requirements and thus relieve the instrument makers of the difficulties due to the control of the Iceland spar supply by a monopoly.

Diffusion of Ions in Gases. E. SALLES. (*Comptes rend.*, cli, 712.)—The diffusion coefficients of the positive and negative ions produced in pure oxygen, nitrogen, carbon dioxide, and air by the rays from polonium were measured. In all cases the negative ions move a little faster than the positive, and the diffusion coefficient decreases with the increase of pressure on the gas. The absolute values of the coefficients agree closely with those found by Townsend for these gases, when using other sources of radiation; this shows that ions produced in different ways are identical.

Siamese Bronze. U. S. VICE-CONSUL GENERAL C. C. HANSEN. (*Metal Ind.*, ix, 7.)—Old records state that the art of bronze casting was introduced into Siam by the Chinese in the eleventh century. Bronze figures of Buddha in perfect condition have been found on the sites of ancient temples, when the buildings which formerly inclosed them have long crumbled away. The native name for this bronze is "Samrit." An old formula discovered by Major Gerini gives the proportions 12 ticals (1 tical = ½ oz. av.) pure tin, melt at a low heat, add 2 ticals mercury, stir until amalgamated, and cast into a bar. Take 1 catty (80 ticals) of refined copper and melt it, and gradually incorporate with it the amalgam. Cover the molten metal with ashes of the bŭa-bok (terrestrial lotus), skim off the dross and the metal is samrit bronze. The proportions will be copper 85.11 per cent., tin 12.77 per cent., and mercury 2.12 per cent.

Action of Nitrogen on the Carburization of Steel. J. KIRNER. (*Metallurgie,* viii, 72.)—A mild steel containing 0.1 per cent. of carbon was heated at different temperatures in case-hardening materials containing known quantities of nitrogen. If there was no nitrogen, no carburization occured. Carburization took place rapidly with materials rich in nitrogen at temperatures between 600°C. and 850°C., it was irregular and slower at 900°C., and became rapid again at 950°C. At 600°–850°C. the outer layer of steel contained 0.6 per cent. nitrogen, as the temperature increased the nitrogen decreased until at 1000°C. it was all eliminated. It is stated that a constituent termed "Flavit" was shown when slowly cooled steels were etched with picric acid, which was absent when the steels were quenched, and presumably passed into solution. The percentage of phosphorus, silicon, and manganese remained unaltered during the process.

Tribo-luminescence. W. S. ANDREWS. (*Trans. Amer. Electrochem. Soc.*, xviii, 279.)—A tribo-luminescent product, that is, one that emits light when rubbed or scratched, is prepared by mixing together 70 parts of powdered zinc carbonate and 30 parts flowers of sulphur to a thick cream with distilled water containing a small particle of manganese sulphate. After thorough trituration the mass is dried at a gentle heat, finely powdered, then packed tightly into a porcelain or plumbago crucible with a tight cover and heated to bright redness for 20 minutes. The product emits sparks of a yellowish light when scratched with a knife; the sparks will not ignite inflammable vapor.

Electrolytic Galvanizing. O. HILDEBRAND. (*Elektrochem. Zeits.,* xvii, 304.)—The difficulties met with in electro-galvanizing are caused by (1) the inconvenience of having entirely to surround the article to be treated (as cathode) with the zinc anode, and (2) the poor adherence of the deposited zinc. In the so-called "regenerative method" the anode is of lead and the electrolyte is zinc sulphate, acidified with sulphuric acid. The solution is continuously circulated through the cell and then through a regeneration vat containing zinc dust before it returns to the cell. Rapid neutralization takes place in the vat owing to the good contact with the finely powdered material. In such a cell the zinc deposit is very pure, adherent and uniform.

The Rusting of Iron. ANON. (*Eng. Record,* lxiii, 296.)—The rusting of iron has been investigated by Messrs. Bertram Lambert and J. Campbell Thomson, at Oxford, Eng. They report that perfectly pure iron, water and oxygen remained in contact for months without rusting, while the slightest impurity, even in the absence of all acids, led to rusting and generally with the lapse of only a few hours.

Publications of the United States Geological Survey.—A new list of publications of the United States Geological Survey, just issued, contains the titles of more than one thousand books and pamphlets. These reports cover a wide range of subjects. They include not only papers on geology and topography but reports on water resources and on technology. The Geological Survey was the nursery of the United States Reclamation Service and the Bureau of Mines, which now, in full growth, are carrying along successfully work begun by the Survey years ago. The Survey, however, still continues its work on water resources and includes discussions of technology in its annual volume "Mineral Resources of the United States."

A glance at this list will show the great diversity of the subjects considered and the manifold nature of the science of geology. The reports include discussions of geologic chemistry, mineralogy, petrography, and paleontology, as well as ore deposition and other matters of very practical importance. Much of the Survey's late work has been directed to the study of mineral deposits of economic value. The work done in land classification has not yet found detailed expression in the Survey's reports, but some papers prepared as a result of land classification surveys have been printed annually in bulletins entitled "Contributions to economic geology."

The list may be obtained by applying to the Director of the Survey at Washington, D. C.

Komposite Anti-friction Metal. (*Iron Age*, lxxxvi, 1448.)—The Komposite Metal Co., has established a plant in Philadelphia, for manufacturing high grade metals, making a journal bearing metal its specialty. This metal has extremely high wearing qualities and melts at from 575° to 700° F. according to the grade of metal. This temperature is about 70° F. above the high tin metals. It has a higher bearing strength and is claimed to have better lubricating qualities than babbitt. Komposite metal, as claimed by the company, is not a mechanical mixture but is "a composite metal, scientifically prepared and chemically united, the chemical union of the various metals being thorough and complete," thus preventing them from separating when cooling.

Fermentation of Citric Acid in Milk. A. W. BOSWORTH and M. J. PRUCHA. (*N. Y. Agric. Exper. Stat. Bull.*, xiv, 43.)—During the spontaneous souring of milk the citric acid present as a normal constituent is converted into acetic acid and carbon dioxide. This change is effected by the action of *B. lactis aerogenes*, and not by any of the common dairy bacteria. Two molecules of acetic acid are produced for every molecule of citric acid present. During the process of cheese making, all the citric acid is fermented before the cheese is placed in the press.

Electrical Advance in 1910. (*La Nature,* xxxix, 127.)—The characteristic of the electrical industry in 1910 has been *concentration;* by increasing the active radius of the central stations, and therefore decreasing their number. The conveyance of power depends on the tension of the current, hence in the United States there are cables with a tension of 135,000 volts and in Europe some, the tension of which exceeds 100,000 volts. Ten years ago a distribution of 10,000 volts was considered marvelous and audacious. Electro-motive force has too been largely applied to railroads; with a lively contest between the monophase and triphase currents.

Light.—Great progress has been made in mercury vapor lamps; the lamp with a quartz tube is much more economical than the earlier lamps with glass tubes. M. Claude has invented the *neon* lamp, which gives a pleasant reddish light at an expenditure of 0.9 watts per candlepower.

The electrical production of steel and iron has made great advances. Steel made in the electric furnace is characterized by its freedom from scoria and gas; by its great malleability when hot, and by its great resistance to shock. Immense castings are made from it, without blisters or pores.

Wireless telegraphy and wireless telephony have made great progress. In wireless telegraphy the system of sparking has been superseded by systems giving musical notes in telephonic receivers.

Hydrogenite. ANON. (*Rev. Scientifique,* xlix, 81.)—This name is given by Mons. G. Jaubert to a mixture of silicol (a metallic silicide) and soda-lime, which disengages hydrogen gas at a certain temperature. The reaction depends on the decomposition of water by silicium in the presence of alkalies, thus:

$$Si + 4NaOH = SiO_3Na_2 + Na_2O + 2H_2,$$

or with the mixture of soda-lime,

$$Si + Ca(OH)_2 + 2\,NaOH = SiO_3\,Na_2 + CaO + 2\,H_2.$$

Instead of silicium, calcium silicide is used, which is a commercial product sold under various names. Hydrogenite is a gray powder, with an apparent density 1, but, when agglomerated, it attains a density of 2.5. One kilogramme produces from 270 to 370 litres of hydrogen, according to the method used. It is produced to use hydrogenite to replace the leakage of gas from balloons.

Explosive "Dont's." ANON. (*Eng. Record,* lxiii, 225.)—The United States Bureau of Mines has issued a number of rules regarding the precautions to be taken to reduce the risks in storing, thawing, handling and using explosives. These were prepared by Mr. Clarence Hall for the guidance of coal miners, and are well worth the close attention of all miners and others who use explosives.

The World's Production of Metals. ANON. (*Mon. Scient., Mercure,* v, 21.)—There were produced in 1909, 844,100 tons of copper, about 100,000 tons more than the previous year, and the consumption increased from 643,700 tons in 1908 to 728,800 tons in 1909. The United States consumed 318,900 tons in 1909, Germany consumed 179,100 tons, England 109,100 and France 73,100.

Of lead 1,052,500 tons were produced. Europe produced 505,800, the United States 339,700, Mexico 118,000, Australia 77,200. The United States used 365,200 tons, Germany 213,200, England 199,500, France 110,400 and Russia 38,300.

There were produced 108,300 tons of tin; 61,500 came from the Straits and 35,500 from Bolivia. Germany produced 8990 tons from Bolivian ores. The United States consumed 42,800 tons; England 17,500; Germany 17,100; France 8,750 and Belgium 1,300.

The United States produced 240,446 tons of zinc, Germany 220,100 and Belgium 167,100. The total production was 783,200 tons.

From a total product of 16,100 tons of nickel, 9,000 were from the United States; 3,100 from Germany and 2,800 from England.

While the consumption of aluminum has risen to 30,800 tons, the production was only 24,200 tons.

Of the 3,200 tons of mercury produced in 1909, England absorbed 1,445 tons and Germany 723 tons.

Commercial Silicon. ANON. (*Mon. Scient., Mercure,* v, 20.)—Commercial silicon is produced at Niagara Falls, by F. I. Tone's process. The furnace used consists of two electrodes plunged into a mixture of coke and sand. A furnace of 1200 h. p. yields 594 to 792 pounds for every five hours. Three qualities are produced containing 90, 95 and 97 per cent. of silicon. The first is used as a deoxidizer in the purification of steel. It is worth $120 per ton by the car-load.

Sical is an alloy of silicon and calcium formed by the reduction of lime by silicon; it is used in the purification of steel.

Commercial Metallic Uranium. W. P. JORRISSEN AND A. P. H. TRIVELLI. (*Chem. Weekblad.,* viii, 59.)—On exposing commercial metallic uranium to cathode rays a considerable quantity of nitrogen was evolved. It was found that the commercial product contained 13 per cent. of uranium nitride (U_3N_4) and 1.25 per cent. of carbon.

Phosphate Deposits in Montana. *Oil, Paint and Drug Reporter,* Feb. 20, 1911.)—The U. S. Geological Survey reports extensive phosphate deposits in and near the canyon of the Big

Hole River, about 30 miles southwest of Butte. It is probable that similar deposits exist over a large part of western Montana. Sulphuric acid for the conversion of the mineral phosphates into superphosphate could be readily obtained from the waste gases of the numerous smelters in that region.

Electric Arc Welding Processes. C. B. AUEL. (*Amer. Mach.*, xxxiv, 479.)—This article describes fully three processes, with their limitations, the apparatus used, the range of work done, the time required, and the results obtained. It also presents suggestions and cautions for their successful application. Undoubtedly this will repay any person interested for its perusal.

Austrian Electrical Directory.—The Electrotechnical Society of Vienna is about to issue a directory of the electrical power stations in Austria and Bosnia-Herzegovina.

The number of electrical stations in Austria is about 800 and they supply current to more than 1,600 cities and towns. The book, which will bear the title "Statistics of Electrical Plants in Austria," will contain the names of the proprietors of the plants with their addresses, the names of the architects, the places supplied with power and much other information relating to the stations, the dynamos and accumulators, the current, motive power, voltage and area supplied. The number of incandescent and arc lamps, the number of meters and motors with memoranda as to their efficiency, as well as data regarding the price of current, capital invested, annual quantity of current produced, etc., will be included.

The work, which has been compiled with the greatest care, will appear in print about July 1st, and will be issued by the Society. As this book, as well as others issued by this Society, is not a money-making venture but is intended for the use of all who are interested in electrical engineering, the price will be comparatively low, and it may be ordered at this time for 2.80 crowns, post paid. After the appearance of the directory the price will be advanced to 3.80 crowns.

The Lost Art of Tempering Copper. ANON. (*Brass World*, vii, 174.)—The Aztecs, Toltecs and Tarascans, it is said, possessed in prehistoric ages the art of tempering copper. Several archæologists and ethnologists of Mexico City now deny they had such knowledge. Copper axes and knife blades found at Atcapotzalco are so soft they can be cut with an ordinary pocket-knife. On the other hand, Tarascan copper cutting implements from the Balsas River ruins in Guerrero were so hard that they would turn the edge of a modern knife. Analysis showed that these different blades were of the same composition as the copper ores found in the respective localities. The soft blades were made from comparatively pure copper ores, while the hard, apparently tempered, blades from Guerrero, were made from the natural ores which existed in the hills, alloyed with nickel and cobalt; thus making the smelted metal (or alloy) almost as hard as steel. Hence the so-called tempering was due to the natural alloy found in the ore, which when heated and sharpened gave a hard, cutting edge. On the other hand, where the ores were practically pure copper, the implements made from such ores were soft and remain so to this day.

New Treatment of Aluminum for Soldering. English Patent of L. MAITRE. (*Brass World,* vii, 171.)—Aluminum can be easily soldered if a thin layer of iron is first deposited on the surface. Then plunge into boiling water and then in cold water. Now re-heat until the deposit has acquired a blue color, and again immerse in cold water, like steel is hardened. This treatment causes the iron deposit to adhere more strongly to the aluminum base. The film of blue oxide is now removed from the surface of the iron deposit on the aluminum by fine emery cloth and the soldering proceeded with by any regular method.

Binders for Foundry Cores. H. M. LANE. (*The Iron Age,* lxxxvii, 1140.)—This gives a full account and description of binders and indicates the proper binder for different kind of sands. The results are thus summarized. The action of core binders must be considered from the following points of view: The core must have sufficient strength to stand up before and during drying. This necessitates the use of a green binder for some classes of work. Flour and dextrine and other gluten products are the best green binders, next to these come clay, glutrin and molasses. Oil, rosin, and pitch are of little use as green binders; but the manufacturers of the black compounds frequently introduce dextrine or clay to serve as a green binder. The most efficient final binder in the dry core would be one in which all of the binder would be gathered at the contact points of the sand, so as to leave the vent passages free. Oil, or blends of oil and glutrin or glutrin and clay, seem to fill these requirements fairly well among the liquid binders, and rosin and pitch among the dry binders. But all the dry binders have a greater or less tendency to roughen the surface of the sand in the vent passages and to partly stop the vents. This is largely true on account of the fact that these binders are generally used with loamy sands or in conjunction with flour and dextrine.

Coloring and Oxidized Finishes. ANON. (*The Metal Ind.*, ix, 203.)—In producing oxidized effects upon coffin hardware some consumers prefer the green gray tone. This is produced by using a weak solution of potassium sulphide to which a little ammonia is added and it is used slightly warm. The articles are immersed without scratch-brushing until the green is produced.

Armor Plating and the Simpson Weld. (*Times, Eng. Supple.*, 1911, xxiii.)—It is stated that whilst Krupp armor is estimated to have 50 per cent. more resisting power than Harveyized armor, Simpson armor is to have a resisting power 75 per cent. greater than Harveyized armor. About 3 years ago W. S. Simpson found that when two plates of steel, with a section of copper between them, were placed in a mixture of carbon, brown sugar, and water of the consistency of compressed snow, and the whole mass submitted to a temperature of 2000° F., the copper melted into the steel and formed a perfect weld. So complete was the union between the two plates that, however treated, they would not part nor split at the juncture. Moreover the copper increased the tenacity of the steel. Samples of such welds were submitted to Prof. J. O. Arnold, who examined them by alternating stress tests and micrographic analysis. Referring to one micrograph he said that it showed " a portion of the thin weld line, in which a considerable part of the copper seam has disappeared owing to the metal dissolving in the steel to form a solid solution micrographically almost indistinguishable from the steel itself. Had the welding been continued for some time longer there would be no visible weld line left, but merely a solution of the copper in the steel, molecularly continuous with the steel itself and considerably stronger than the main body of the metal, because the copper will have disappeared (visually) after having brought into perfect continuity the molecules of both faces of the steel."

Application to Armor Plating.—As is well known, by the face-hardening processes which have been in use for some time past, carbonization of the armor plate does not extend deeper than ⅞ of an inch. A hard face and a tough back are obtained, but the hard face is neither as hard nor as thick as could be wished. If, then, it were possible to take high speed steel, say of double this thickness, and weld it to a soft steel backing, an immense advantage would be gained, and that is what the Simpson weld can do. Not only is the high-speed steel many times harder than ordinary steel, but the hardened face of the plate can be made of any desired thickness. It is understood that trials have been made already with plates of the usual regulation size in which 2 inches of hard steel were welded to 4 inches of soft, and which gave entirely satisfactory results when attacked by a 6-inch gun.

" Coslettizing " or Rust Proofing of Iron and Steel. EMMANUEL BLASSETT, JR. (*The Metal Ind.*, ix, 207.)—This finish is a dilute solution (about 4 per cent.) of phosphoric acid mixed with iron filings, kept at boiling temperature. The process is very simple and always produces good results. The metal to be treated is first immersed for a few seconds in a boiling solution of potassium or sodium hydroxide (caustic) and if rusty or greatly tarnished is put through the regular sulphuric acid pickling solution. It is then rinsed in water and placed in the "Coslettizing" solution. kept at the boiling point for 2½ to 3 hours. When completed the metal has a greenish-black appearance. It is dried, then oiled with linseed or paraffin oil, which gives it a gray-black color.

Spontaneous Combustion of Coal. A. W. PARR and F. W. KRESSMAN. (*J: Ind. Eng. Chem.*, iii, 151.)—Oxidation processes begin in freshly mined coal at ordinary temperatures, and they are of different character and vary in their speed and intensity. In general each kind of coal has a critical temperature of oxidation, below which the process, resulting from external factors, does not prove ultimately destructive and stops when the exciting causes are removed; but above this temperature the oxidation becomes autogenous and results in the ultimate destruction of the coal. Auto-oxidation begins at 200° to 275° C., according to the fineness of division of the coal, while ignition does not occur under 550° C. The temperature of autogenous oxidation depends upon a number of factors, which include: (*a*) external sources of heat, (*b*) fineness of division, (*c*) easily oxidizable compounds, (*d*) iron pyrites, (*e*) moisture, (*f*) oxidation of carbon and hydrogen. Autogenous oxidation begins at 200° C., to 275° C., while above 300° C. an exothermic decomposition begins and raises the temperature until ignition occurs usually at 350° to 400° C.

Separation of Metals from Complex Ores. H. L. SULMAN and H. F. K. PICARD. (*Eng. Pat.* 8650, 1910.)—This process is applicable to any mixture where one of the metals is more easily reducible than the other. A mixture containing the oxides of zinc and lead is crushed and heated with carbon, or in an atmosphere of reducing gas, to a temperature of about 600° C., when the lead alone is reduced to metal, distributed in small particles through the mass. The product is cooled, under conditions preventing re-oxidation and then concentrated by vanning or flotation, to separate the lead particles; the zinc and silica being left in the watery pulp. Sulphide ores must first be calcined; should any sulphide of the more easily reducible metal be oxidized to sulphate, it will be again reduced in the final reduction and can be easily separated.

Sterilization of Water by the Quartz Lamp. (*Eng. Record*, lxiii, 485.)—Considering the great interest in the sterilization of drinking water by various means, it is surprising that so little has been done with the quartz-mercury lamp in this country. The foreign reports indicate so great bactericidal power in the radiation from the quartz lamp as to make it worthy of careful study as a practical means of sterilization. The effective rays are those of extremely short wave-lengths, so short that they are wholly stopped by glass and do not escape from the glass tube usually used in mercury lamps. These short radiations, having a wave-length of approximately 0.00001 inches, get through the quartz lamp and are still very powerful at a distance of 1 or 2 feet, though they are readily absorbed by air. Cernovedeanu and Henri made some experiments, which give very striking data as to their rapidly destructive action on bacteria, when the water is within a short distance of the tube, 15 to 20 seconds exposure completely destroyed *B. coli* and many other forms of bacterial life. The water is led in a circuitous channel so that it passes repeatedly within the effective radius of action of the quartz lamp, and produces very complete sterilization. Its only effect on the water is to produce very slight traces of hydrogen peroxide. The energy required for the lamp is an ordinary continuous current at 110 or 220 volts; this requires no special apparatus and no attention. This simple and effective process will, it is to be hoped, be thoroughly tried out in this country so that its field of usefulness will become clearly known.

Cupror, a New Alloy. ANON. (*The Metal Industry,* ix, 95.)—Cupror is a newly discovered alloy of copper and aluminum, of gold-like appearance. Its tensile strength is 93,000 lbs. to the square inch. Its gold-like appearance and lustre are unchanged by atmospheric conditions. It has remarkable toughness and ductility, and can be drawn, spun and handled in every conceivable way with facility. Its close resemblance to 18-carat gold deceives even jewellers. It is valuable for the manufacture of brass bedsteads, automobile fittings, ship fittings, building hardware, railroad car fittings, chandeliers, etc.

Chinese Jewelry Made in Germany. U. S. Consul J. C. McNALLY, Tsingtan, China.—Germans are now producing imitation Chinese jewelry embossed with Chinese characters signifying " longevity " and "good-luck," heretofore exclusively manufactured by the leading Chinese firms of Canton and Hongkong; such as cuff links, watch fobs, cravat pins, brooches and so forth. The German goods are of superior workmanship, but the grade of gold is only 14 carat, while the Chinese grade runs from 18 to 24 carat. Moreover, the Germans have produced an artificial jade stone, so close to the real Chinese jade that dealers themselves can be deceived. The Chinese houses are about to substitute the imitations in their mountings, and when travellers in the Orient purchase jade ornaments, they should bear these German imitations in mind.

Pickling Aluminum. ANON. (*The Metal Industry,* ix, 79.)—To free aluminum from grease, oxide or other foreign substances, and to give it a good surface, the German Aluminum Industry Co. uses a hot 10 per cent. solution of sodium bicarbonate, saturated with common salt. The articles are dipped therein for 15 to 20 seconds, taken out and brushed; dipped again for half a minute, well washed with water and finally dried in saw-dust. This gives them a color like matted silver. If only a good polished surface is desired it is enough to dip them in a dilute solution of caustic potash, then rinse and dry thoroughly.

Smoke Prevention in England. U. S. Consul CHAS. N. DANIELS, Sheffield. (*The Metal Industry,* ix, 79.)—A smoke consumer and fuel economizer was successfully demonstrated in Rotherham, before the members and officials of the corporation. It is said to be the result of 20 years' experimentation. Coal was fed to the furnace of a boiler with the usual result, the emission of black smoke from the stack; then the consumer was put in operation and, at once, the black smoke disappeared, and there was only a trace of the products of combustion.

The effect is produced by a series of devices so placed in the flues as to intercept the smoke and cause it to be ignited by the flame. Two air circulators are so placed as to allow the desired quantity of external air to be circulated among these devices, causing the smoke to be properly ignited and consumed, before reaching the chimney. There is nothing to get out of order and a saving of fuel is claimed. The apparatus can be affixed to almost any type of boiler during a week end.

Handling Iron Ore With Electric Magnets. ANON. (*Iron Age,* lxxxvii, 431.)—The *Electrical World* states that at Moose Mountain Mine in Ontario, Canada, high-grade magnetic iron ore is picked from the ground and loaded into cars by electro-magnets. The ferrous material found on the side of a hill is loosened and broken down by blasting, and rolls to the foot of the hill, where an electro-magnet, mounted on a crane, picks it up and loads it into mine cars, at the same time making a rough separation, since rock and non-magnetic material are left behind. The electro-magnet can handle 1200 lbs. of pig-iron at a load, but the magnetic quality of the unrefined ore is such that 800 lbs. can be picked up easily. This is the average of a number of loads the individual lift sometimes being several hundred pounds greater. A steam shovel was formerly used for loading the ore, but the density and hardness of the magnetite destroyed the buckets rapidly. The electro-magnets also save handling a quantity of stone, and thus relieve the crushing and magnetic separating plant, where the material is concentrated before being shipped.

Tinning Articles of Gray Iron, Malleable Iron and Steel. C. H. PROCTOR. (*The Metal Industry,* ix, 68.)—Although electro-galvanizing has greatly advanced in the last decade, and the zinc protects the iron from rusting, yet galvanizing will never replace tin for culinary and other household articles; for tin is the more attractive metal and not poisonous as is zinc. Electro-tinning does not seem likely to replace molten or dip tinning. The process of hot tinning may be summarized as follows:

I. Cleansing from sand or scale by pickling in hydrofluoric acid, at 5° to 10° Beaumé.

II. Tumbling in an ordinary tumbling barrel, using sal soda and water as the medium, for thirty minutes to one hour.

III. Washing in cold water and immersing in a 5 to 10 per cent. solution of hydrochloric acid to remove oxidation. Then immerse in a flux of concentrated zinc chloride. Four to five pounds of sal-ammoniac (ammonium chloride) is added to each gallon of the acid.

IV. Drain the articles well and immerse in the molten tin pot, where they remain until they get sufficiently hot and are thoroughly coated with tin. Remove from the bath and throw off the excess of tin by a quick motion. This is the first coating. The bath should be at 500° F.

V. Quickly immerse in the second or finishing bath, at a temperature of 400° F. The surface should be covered with a mixture of five pounds beef tallow with one pound of palm oil, to a depth of from one-half to two inches. This acts as a flux, makes the tin run freely, prevents oxidation and gives a more uniform coating. The excess of tin is removed by slinging motions, and then the article is immersed in kerosene oil, kept as cold as possible by a jacket of cold water, to keep down the temperature and prevent ignition.

VI. Now plunge the articles in clean, boiling water to remove as much kerosene as possible, and dry with cheap wheat flour or fine maple sawdust. Sometimes three or four tinning kettles are used, each at a lower temperature, when a heavier coating is required.

Straits of Banca tin should be used for good results. The process can be cheapened by adding from 25 to 50 per cent. of lead. Small articles are tumbled dry to polish the surface.

The Displacement of the Zero Point in Balances of Great Precision. M. MANLEY. (*Rev. Scientifique,* xlix, 500.)—Small irregularities are frequently noticeable in very delicate balances. These are troublesome in operations requiring very exact weighing; such as the determination of atomic weights, measuring the density of the earth, standardizing weights, etc. The reason of this displacement has been studied theoretically and experimentally. The change in the position of equilibrium of a balance is due to the following four causes: (1) Lateral slipping of the central knife-edge on its support; (2) variable and continuous flexion of the beam after loading the pans; (3) lateral displacement of one or several knife-edges; (4) small differences in temperature between the two arms of the beam. The two first causes have no appreciable practical effect; the two last are the actual causes. With regard to the temperature it has been shown by means of a very sensitive differential bolometer that there is a slight but rapid and almost continuous variation in temperature of the air immediately surrounding the beam. Further, when the pans have just been loaded the changes of temperature of the two arms of the beam are markedly increased; so that it is necessary for taking an exact weight to wait 10 or 15 minutes before taking the final reading. It is also necessary to "fatigue" the beam by letting it oscillate freely for a certain time after loading the pans. The quantity which expresses the displacement of the zero point of a very precise balance is a very regular function of the temperature of the beam. These irregularities can be overcome to a great extent by using a small cover around the beam of the balance, to protect it from external heat and convection currents.

Copper Poisoning. C. A. HANSEN. (*Gen. Elect. Research Laby, Met. Chem. Eng.*, ix, 67.)—This is a warning to those working with copper in an electric arc furnace of the poisonous effect of copper fumes. Ten men, all old hands in smelting work, were melting 5000 pounds of pure electrolytic copper scrap in a 3-phase arc furnace. The run occupied 5 hours, and 3 hours after pouring off they suffered great inconvenience in respiration, and for 24 hours severe nausea and soreness were experienced, similar to an attack of acute grippe. The run was made under the most favorable conditions as to ventilation, so that if the ventilation had been poor the results would probably have been very serious.

The Action of Ultra-Violet Rays on Rubber. V. HENRY. (*Caoutchouc Guttapercha*, vii, 4371.)—The action of the ultra-violet rays on raw para, plantation rubber and the rubber obtained by the evaporation of *Hevea latex* was investigated. The last was attacked by the light, entirely losing its elasticity and becoming sticky. The plantation rubber was not attacked so greatly, the Para least of all. Vulcanization greatly increases the resistance to the rays, as does the addition of mineral matter. The action of the rays is really an oxidation, since the rubber is not attacked if exposed to the rays in evacuated quartz tubes. The rays with the largest coefficient of refraction are the most active. As the higher atmospheric regions are rich in ultra-violet rays, these experiments are of practical value on choosing rubber coverings for balloons.

Specifications for the Quality of Gas. H. BUNTE and H. STRACHE. (*J. Gasbel*, lii, 817.)—With the extensive use of gas for heating and lighting purposes, the candlepower standard of measuring the quality of gas is both inadequate and misleading. Candlepower measures only the light producing power of gas when burned in an open flame; it tells nothing about its value for heating purposes. The researches of St. Clair Deville in 1903, and the more recent ones of Bunte and his assistants, have shown the remarkable fact, that within certain limits and certain well defined conditions the light-giving power of gas is proportional to its heat value; or with the same gas, the light emitting power of the incandescent mantle is proportional to the number of heat units fed to the burner per unit of time. This is not an exact law, but a serviceable rule. The true value of gas, then, both for light and heat can be measured by its calorific power, this is the only logical measure. A gas having a calorific value of 5,200 cal. per cubic metre is recommended as the standard. The latest designs of burners for heating and lighting require that the gas should have an approximately constant composition, since the maximum efficiency of the burner is only obtained when the relative amounts of air and gas are closely regulated. Water gas may be added to prevent excessive variations in calorific value. Gas should be free from hydrogen sulphide, cyanogen, and ammonia. The gas producer should choose that coal which on distillation yields the greatest part of its heat value in a gaseous form.

Installations of Girod Electric Furnaces. (*Elec. Rev.,* lviii, 300.)—Six Girod furnaces are at work at Ugine, France, on cold charges. Two with four electrodes refine 18 tons of cold scrap or 20 tons of molten scrap, with a power of 1200 to 1500 k.w. Two others with a single electrode, at 325 to 350 k.w., have a capacity of 3 tons cold and 4 tons hot. Two furnaces of 2 tons capacity are also in use, and a new 8000 k.w. power furnace is being installed. The product is high-grade tool steel, projectile steel and steel for castings, auto-frames, etc. The Girod Co. has 40 furnaces operating on ferro alloys. The Cockerill Co., Belgium, and Krupp & Co., Germany, and the Simonds Mfg. Co., Chicago, are all using Girod furnaces to produce high-grade steel.

The Effect of Copper on Nickel-Plating Solutions. (*Brass World,* vii, 45.)—Experiments to ascertain the effects of copper on nickel-plating solutions, gave the following results: (1) The pressure in a nickel-plating solution of as small an amount of copper as 1/64 oz. to the gallon is appreciable and slightly darkens the nickel deposit. This is about 1 per cent. of the quantity of nickel present. (2) When the quantity of copper is increased the nickel deposit becomes still darker and a smut forms. Therefore, the presence of copper must be regarded as an injurious ingredient in a nickel-plating solution.

Production of Tungsten Wire for Lamp Filaments. (*Elect. Rev. and West. Electrician,* lvii, 790.)—Particles of metallic tungsten are first heated in a practically closed crucible and phosphorus introduced from time to time in small quantities, but sufficient to convert all the tungsten to tungsten phosphide. In this way relatively small amounts of tungsten phosphide are produced, but as it is fusible a large number of these particles are put into the crucible and fused into a single ingot. This phosphide ingot is then made the cathode in an electrolytic bath to reconvert it to metallic tungsten. This renders it more or less porous. To make it compact it is subjected to a white heat under an oxy-hydrogen blowpipe while being simultaneously worked by hammering and rolling. The heat must not be high enough to cause oxidation. The ingot is cooled and the process repeated to make it more homogeneous and ductile. When the requisite tenacity is attained the ingot is hammered and compressed to a long drawn-out rod. This is cooled and again heated, but to a lower temperature, and drawn out to a wire by passing it through suitable dies. This wire is claimed to be so ductile and flexible that it can be formed into any shape of filament.

Application of the Thermopile to Photometry. J. G. Felton and E. J. Brady. (*Amer. Ill. Eng. Soc. Trans.*, v, 729.)—A description of the application of the thermopile to determine polar curves of a large number of illuminants, comparing the curve obtained photometrically with that of the thermopile. In glow lamps the agreement was good, but incandescent gas lamps, which generate heat, give abnormalities. The results are also complicated by glass reflectors, some of which are much more transparent to light than to heat.

Atherium; a New Alloy. (*Electrician*, lxvi, 525.)—This is a new, white metal alloy, lighter than aluminum, its specific gravity is 2.4 to 2.57. A test-piece 0.628 inches in diameter gave an elastic limit of 33,712 pounds per square inch, an ultimate strength of 41,798 pounds per square inch, an extension of 17.5 per cent. on 2 inches, and a reduction of area of 39.1 per cent. This alloy gives sound castings, rolls and turns well, and can be soldered, forged and welded. It is claimed that it does not tarnish nor corrode and withstands the action of sea water.

Advantages of Unified Electric Systems Covering Large Territories. W. B. Jackson. (*Amer. Inst. Elect. Eng. Proc.*, xxx, 173.)—These advantages are mentioned: (1) Saving in power-house equipment through taking advantage of the diversity of different communities by serving them from the same transmission system. (2) Lower cost of power generating per k.w. hour, due to larger power plants and improved load factor. (3) Smaller investment in power plants per k.w. capacity in larger plants as compared with smaller. (4) The possibility of decreased percentage of spare apparatus by appropriate arrangement of power plants. (5) Saving in cost by centralized management, general superintendence, and other general expenses. (6) Possibility of providing rural and suburban service that could not be profitably done by a local central station. (7) The possibility of large corporations providing power service that would be too expensive for small companies. (8) The development of water power for electric service.

Micrographic Examination of Cast-Iron in the " Graphitized " Condition. O. KRÖHNKE. (*Metallurgie,* vii, 674.)—A peculiar decomposition of cast-iron tubes converts them into a soft dull gray or dark brown mass, somewhat similar to graphite, while they retain their external shape. There are various methods of causing this change, and the converted material has a specific gravity of approximately 2, and can be cut with a knife. Tubes of various compositions have been buried in the earth and then, at different degrees of conversion, examined micrographically. One specimen with a normal composition: total carbon 3.81 per cent., graphite 2.96, sulphur 0.097, manganese 0.55, silicon 2.33, phosphorus 1.850, iron 91.82 per cent., was converted to this composition—total C, 9.85 per cent., graphite 8.83, S 0.518, Mn 1.10, Si 4.25, P 3.60, Fe 68.6 per cent. Apparently the changes are: (1) Pearlite disappears, but only the ferrite is dissolved from it; (2) the graphite remains, but is converted into a peculiar grayish-white or white modification according to the extent of the conversion (Graphitierung) ; (3) cementite and the phosphide eutectic remain unchanged. White iron containing no graphite, and wrought iron tubes, do not appear to undergo the change. It seems, therefore, that the destruction of the tubes is caused by electrolytic action set up between the graphite and the other constituents of gray iron.

Planck's Formula for Diffusion Potentials. N. BJERRUM. (*Zeit. Elektrochem.*, xvii, 58.)—It is shown that in certain cases Planck's formula is not reliable and Henderson's formula is preferable. An experimental arrangement is given where Planck's formula is valid.

Observations of Humidity on Mars. J. HANN. (*Meteorological Zeitschr.*, xxvii, 522.)—An expedition was made from the Lick Observatory to the summit of Mt. Whitney to endeavor to determine amount of water vapor present in the atmosphere of Mars. The results depended on the degree of exactness with which the humidity of the earth's atmosphere could be determined. Then by comparative spectra of the Moon and Mars at about equal altitudes, the intensity of the " *a* " water-vapor red band was measured. The conclusion arrived at was that there was little evidence of the presence of more water-vapor on Mars than on the Moon.

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BY

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Sacred, profane and mythological literature abound in incident, fact and fancy, showing that from earliest times man has sought to assuage grief and pain by some means of dulling consciousness. Recourse was had to the inhalation of fumes from various substances, weird incantations, applications of drugs, both external and internal, pressure upon important nerves and blood-vessels, and the laying on of hands, or animal magnetism. Each has played its part in the mitigation of human ills. It was not until the close of the eighteenth century, however, that modern surgical anæsthesia was foreshadowed. Then it was that the discovery of hydrogen, nitrogen, oxygen, and nitrous oxide—pneumatic chemistry, as it were—created a field of pneumatic medicine. In 1798, the Pneumatic Institute was founded for the purpose of investigating the "medical powers of factitious airs or gases" and was set up at Clifton by Dr. Thomas Beddoes. The immediate idea to be followed out was the treatment of phthisis and other lung troubles by inhalation of various gases. Humphrey Davy was assigned the office of superintending the experi-

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* Presented Wednesday evening, June 14, 1911.

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ments. One of the first outcomes of his researches, the result of his experimentation with nitrous oxide upon animals, is given in the following historical and often quoted sentence[1]:

"As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used to advantage during surgical operations in which no great effusion of blood takes place." Davy actually inhaled the gas, and recorded his own sensations and the behavior of others after they had inhaled it.

In 1805 Dr. Warren, of Boston, used "sulphuric ether" on a patient suffering with phthisis, and the year following it was used in attacks of asthma; but Faraday in 1818 was the first to recognize its value as an anæsthetic.

Chloroform was discovered in 1831 independently by Liebig. Soubeiran and Guthrie. It is reported in the *American Journal of Science* for January, 1832, that Dr. Ives, of New Haven, used chloroform in surgery.

In 1828, Girardin read a paper describing surgical anæsthesia by means of inhaled gases; but the honor of the discovery of surgical anæsthesia has been claimed, with more or less acrimonious partizanship, for four others, namely, Long, of Jefferson, Ga., who anæsthetized a patient with ether in 1841; Wells, of Hartford, Conn., who used nitrous oxide in dentistry in 1844; and Morton, a pupil of Wells, used ether instead, at the suggestion of Jackson, a chemist, who later claimed to be the real discoverer. Simpson, in 1847, first used ether in midwifery and later he employed chloroform, whose anæsthetic properties had been previously described by Flourens. In 1868 Andrews, of Chicago, called attention to the use of oxygen with nitrous oxide to produce a non-asphyxial form of anæsthesia. In 1906, Brown, of Cleveland, used a warmed mixture of nitrous oxide and oxygen, followed by ether and chloroform, with great success. In 1909, Gwathmey, of New York, moistened the gases.

I need not recount the historical data which have to do with other anæsthetics, a list of which I have published in the *American Druggist*, and my remarks this evening will therefore be limited to nitrous oxide, ether and chloroform; and these few facts—the results obtained from careful unbiased investigation of the literature and other forms of evidence—are given without elaboration or argument.

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[1] Davy "Researches, Chemical and Philosophical, chiefly concerning Nitrous Oxide," London, 1800.

The writer knows of no satisfactory basis of classification of anæsthetics. Some are general, others local, but the latter may become general in their effects, depending upon conditions. Hence, they will be considered in chronological order.

NITROUS OXIDE.

In 1772, Priestley first prepared nitrous oxide by reducing NO with moist iron filings. In 1793, Deiman and others prepared the gas by heating NH_4NO_3, essentially the commercial process for its manufacture to-day. It is usually carried out by heating mixed salts, as $NaNO_3$ and $(NH_4)_2SO_4$, $NaNO_3$ and NH_4Cl, etc.[2]

Commercial nitrous oxide is apt to contain these impurities: Cl_2, NO, NO_2, HNO_3, NH_3, HCl, CO_2, O_2, N_2, and the rare gases of the air. It is usually purified by passage through solutions of sodium hydroxide, ferrous sulphate, and sulphuric acid. Further purification may be accomplished by the formation of a hydrate[3] below 0° C. and heating this hydrate ($N_2O,6H_2O$)—that is, by fractional condensation[4] and by fractional distillation.

The following impurities may be suspected in a cylinder of compressed nitrous oxide:

1. Solids.
2. Liquids.
3. Gases and vapors:
    H_2O,
    halogen acids, HNO_3, organic acids,
    O_3, NO_2, N_2O_3, SO_2,
    NH_3, organic bases,
    CO_2, halogens, oxides of chlorine,
    HCN, $(CN)_2$,
    PH_3, SbH_3, AsH_3, H_2S,
    O_2, H_2,
    CO, CH_4, organic matter (from valve lubricants),
    N_2, rare gases of the air.

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[2] Baskerville and Stevenson, *J. Ind. and Eng. Chem.*, iii, No. 8.

[3] Villard, *Compt. rend.* (1894), cxviii, 1096.

[4] Stolzenberg, *Ber.*, xliii, 1708.

For these impurities, a qualitative search should first be made and then, whenever necessary, a quantitative determination. A systematic procedure has been devised, a detailed account of which on this occasion would be unwelcome. Those substances known to be irritant to the respiratory organs should be tested for to make sure of their absence before the gas is used in surgical cases. It may be said that established manufacturers appreciate this and govern themselves accordingly, consequently it is not necessary to test every cylinder supplied by them. Their integrity constitutes an asset—a fact which, unfortunately, is not the case with all manufacturers of all drugs.

Beyond the absence of disturbing impurities, the improved methods of the use of nitrous oxide for anæsthetic purposes demand a knowledge of the approximate content of nitrous oxide in the commercial product, as will become apparent later; hence a method for its determination is desirable. Various methods have been proposed—for instance, decomposition into N_2 and O_2, burning with hydrogen, explosion with hydrogen, combustion of charcoal with absorption of CO_2 produced, explosion with CO, oxidation of a fused mixture of sodium carbonate and Cr_2O_3 and determining the amount of Na_2CrO_4 produced, and absorption in alcohol; and none is satisfactory. Dr. Stevenson and the writer have devised a new method, which gives accurate results in hands skilled in the manipulation of gases. It depends upon passing a definite quantity of the gas over heated copper gauze, after a preliminary treatment to remove oxygen or compounds which produce copper oxide from the sample, and then passing hydrogen through the apparatus, and absorbing the water formed.

TABLE I.

ANALYSIS.

No.	N_2O	H_2O	CO_2	NH_3	O_2	N_2, etc. by diff.	N_2O by explosion	N_2O by Cu + CO_2 + H_2	N_2O by Cu + H_2
1	99·7	0.13	0	0.006	present	0.16	97·5	99·4	99·7
2	96.6	0.15	0	0.001	present	3·25	95·0	96.2	96.6
3	99·5	0.15	0	0	present	0·35	97·3	99·5	99·5
4	95·9	0.16	present	0	present	3·94	94·1	95·6	95·9

Table I, which is self-explanatory, exhibits the results of our analyses of compressed nitrous oxide as supplied by American manufacturers.

Nitrous oxide which is to be used for anæsthesia, should contain at least 95 per cent. of N_2O and no solids, liquids, combustible organic matter, chlorine, or other oxides of nitrogen. A small amount of carbon dioxide, according to the investigations of Gatch, can have no evil effects. If present, however, the percentage should be known.

ETHYL ETHER.

Experiences of expert anæsthetizers, often not accounted for by idiosyncrasy, obtained in the use of ethyl ethers supplied by various manufacturers in numerous surgical cases, furnished the motive for this phase of the investigation of the chemistry of anæsthetics. The standards laid down by the various pharmacopœias of the world are not uniform. In view of that fact alone, a thorough investigation seemed called for. Enquiries addressed to large consumers of the solvent in manufacturing processes adduced further need for satisfactory methods of determining the purity of ethyl ether and of detecting impurities introduced, or proving their absence if eliminated, in the modification of raw products used in its manufacture. The presence of small amounts of substances has oftentimes been the cause of a chemical reaction proceeding in a particular direction by virtue of a "catalytic action." So the presence of even traces of certain substances, as peroxidized compounds, aldehyde, etc., may have caused some reactions to be incorrectly explained, or to follow an unusual, or unaccounted for, route.

Ethyl ether is still made commercially by the historical process of treating alcohol with sulphuric acid—hence the misnomer of "sulphuric ether," or "vitriolic ether"—although other synthetic processes have been proposed, some of which have been tried out, but always without commercial success.

In this connection reference may be made to the method devised by Fritsche for the preparation of ether free from alcohol. In this method gas containing ethylene is treated with sulphuric acid,[5] and the ethyl-sulphuric acid so obtained is converted into ether and sulphuric acid by means of water. It was reported that this process was operated on a commercial scale in this country for some time, but that the industry was destroyed by the Denatured Alcohol Act.[6] It is likely, however, that a similar industry may be revived, as natural gas might serve as a suitable material from which to prepare ether.[7]

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[5] *Z. anal. Chem.*, xxxvi, 298; U. S. Patent No. 475,640, Jan. 10, 1897.

The quality of ethers on the market depend upon, first, the purity or grade of the alcohol used; and, second, secondary reactions which take place, not only with impurities in the alcohol, but with ethyl hydroxide itself. For example, ethyl ether made from ethyl alcohol denaturized by methyl alcohol contained other ethers, as dimethyl oxide or methyl-ethyl ether, not found in the ether made from the old rectified spirit. The generous interpretation of the denatured alcohol act by our Government officials, whereby alcohol denaturized by ether itself may now be used, eliminated these substances. Many of the impurities traceable not only to the quality of the raw products used, but the secondary reactions of their virgin impurities, due to variations, as in temperature, pressure, and other conditions, were removable and have in a large measure been removed, or much reduced, by subsequent purification.

It was found necessary in our work to make discriminations in the various grades of ether,[8] so the following classification was settled upon and its adoption by others is suggested:

1. *Pure Ether.*—Absolute ether—ether free from all impurities.

2. *Anhydrous Ether.*—Ether free from water, but which may contain traces of ethyl alcohol and acetaldehyde.

3. *Anæsthetic Ether.*—Ether complying with the pharmacopœial requirements. Such ether may contain ethyl alcohol (up to 4 per cent.), and traces of acetaldehyde, acids, and water, although in the opinion of the author, it is highly desirable that the three last mentioned,—*i.e.,* the impurities,—be totally eliminated.

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[6] *Bull. 92,* U. S. Dept. of Commerce and Labor, Bureau of the Census, 1909, p. 96.

[7] Cf. French Patent 352,687, of 1905, of Lance and Elworthy.

[8] Chas. Baskerville and W. A. Hamor, *J. Ind. and Eng. Chem.,* iii, 301, 378.

4. *Commercial Ether.*—Ether which contains at least 95 per cent. by weight of ethyl oxide.

All other grades of ethyl ether should be classed as *Impure Commercial Ether.*

The standard of purity for laboratory ether, or ether for analytical purposes, is entirely dependent upon the purpose for which it is intended. For ordinary reagent purposes, the grade specified under *Anæsthetic Ether* is suitable, and in general may be said to answer all such purposes; but in special cases the other ethers may be employed. Our attention will be confined to anæsthetic ether.

The specific gravity of ether intended for anæsthesia should not exceed 0.720 at 15° C., providing an ether containing minimum quantities of alcohol and moisture is required; however, an ether which shows a specific gravity of 0.7215 (2 per cent. absolute alcohol), 0.7228 (3 per cent. absolute alcohol) or even 0.724 (4 per cent. absolute alcohol), providing the sole "impurity" is ethyl alcohol, is acceptable for anæsthetic purposes according to various pharmacopœias.

In this connection it may be stated that for various reasons a pure ether may be diluted with ethyl alcohol when it is to be used for anæsthesia. Impurities then observed may be due in part to the alcohol used in dilution. Practically all ethyl alcohol contains some acetaldehyde.

Ethyl alcohol serves, it is asserted, as a preservative for ether when the latter is properly stored; and small amounts interfere in no way with the application of ether in anæsthesia. However, the presence of alcohol is unnecessary except when ether is administered by the "drop method." In this case, the presence of alcohol prevents too rapid volatilization and consequent chilling of the apparatus with which the ether is administered. Some have maintained that pure ethyl ether is unsuitable for anæsthesia, but it is a fact that the vapor from ether containing alcohol, when passed through water at 40° C., whereby the alcohol is removed, may be and is being used now with great success for anæsthesia. The presence of excess moisture in liquid ether should be guarded against, since ether in contact with water, or moist air, in time gives rise to various impurities of an objectionable nature. Thus anæsthetic ether even of proper grade may develop impurities to be avoided quite as much as if they had been introduced in the original materials or later produced in the manufacture or added in the preparation for distribution in commerce.

Instances of sophistication have been known, but now they are comparatively rare. There are more frequent instances of contamination resulting either from the lack of control in the manufacture or from careless storage. It is almost needless to call attention to the necessity for having a substance such as anæsthetic ether, which is used so extensively in the most critical cases, as pure as human ingenuity can provide it.

Traub pointed out that a sample of " impure " ether usually leaves a fruity odor when allowed to evaporate on filter paper, and it is generally recognized that filter paper which has been moistened with ether must possess no odor after the evaporation of the ether. This test is given in the pharmacopœias of Austria, Belgium, Japan, Switzerland, Spain, Great Britain, Germany, and the United States. Generally a positive result may be said to be indicative of the presence of " heavy oil of wine," amyl, propyl, or butyl compounds, or fusel oil. These materials, if present, may excite coughing during inhalation. The occurrence of fusel oil and of " heavy oil of wine " is rare in the case of anæsthetic ethers and they are really only likely to occur in commercial and impure commercial ethers.

Ether, when freshly distilled over sodium, possesses a specific gravity of 0.7178 to 0.719 at 15/4° C.; but if it is not, immediately after its rectification, drawn off into vessels, which are sealed at once and carefuly stored, the specific gravity increases in a short time. The purest ether procurable on the market is of 0.718–0.719 specific gravity at 15°, but this absorbs water on exposure to the atmosphere, and rises to 0.720–0.721 specific gravity, when it becomes fairly constant.

Since the specific gravity of ether is 0.7178 to 0.719 at 15° C., those requiring ether of 0.720 specific gravity thus allow minimum amounts of water and alcohol. Unless the ether is dried carefully by means of sodium, for example, and is kept constantly dehydrated by storing over such an agent, or great care is taken in storing it after final rectification, it is practically impossible to maintain the specific gravity originally possessed by the ether.

The ethers recognized as official by the pharmacopœias of various countries possess the specific gravities shown in Table II.

Although the boiling point of pure ether is + 34.6° at 760 mm., there are no ethers of anæsthetic grade on the market which comply fully with this requirement, owing to the mutually opposing influences of water and alcohol on the boiling point, and only ether distilled over sodium closely approximates it. Since, therefore, these influences render the constancy of the boiling point as ordinarily determined of little or no use as a criterion of purity, it is sufficient to require that ether shall commence to distil at a temperature not under + 34° C., and that it shall possess a boiling point of + 34° to 36° C. We have found that ether purified by distillation over sodium yields a distillate amounting on the average to 99.50 per cent. of the total amount taken when fractioned, this percentage distilling off between + 34° to 35° C.; whereas three ethers used for anæsthesia gave the results shown in Table III.

TABLE II.

Specific gravity.	Countries where recognized.
0.716–0.717	United States.
0.720	Russia; Great Britain; Mexico; Spain; Japan; Germany; France; Belgium; Sweden; Holland; Hungary.
0.720–0.722	Switzerland; Italy; Norway; Denmark.
0.725	Austria.
0.724–0.728	Finland.
0.728	Portugal.

TABLE III.

Temperature.	Percentage by volume.		
	I.	II.	III.
25°–34°	1.00	1.00	1.00
34°–36°	98.50	97.00	97.50
36°–37°	0.50	2.00	1.50
37°–42°	....	....	....

In view of these facts, augmented by other experiments, the writer is of the opinion that ether intended for anæsthetic purposes should, when carefully fractionated, yield a distillate amounting to at least 97 per cent. by volume between + 34° and + 36° C., and that not more than 1 per cent. should distil off below + 34° C., if it is to comply with present pharmacopœial requirements.

Ethers recognized as official by various countries possess the boiling points shown in Table IV.

The writer, assisted by Mr. W. A. Hamor, has conducted an extensive investigation of the changes which occur in ethyl ether during storage, and the experimental data obtained lead to the conclusion that the oxidation of ether in the presence of moisture is productive of a series of complex conversions, initiated, however, by the formation of hydrogen dioxide. The slow combustion of pure ether in the presence of water, and under such conditions as exist when it is improperly stored, would appear to occur in the following stages:

1. The formation of hydrogen dioxide from water and oxygen of the air. This is particularly likely in cases where there is direct exposure to light, and it is more or less activated by contact action.

TABLE IV.

Boiling point.	Where recognized.
34.5°	Great Britain.
34°–36°	Finland; Austria.
35°	Hungary; Japan; Germany; Belgium; Russia.
35.5°	United States.
35°–36°	Switzerland.
36°	Italy; Norway; Denmark; Portugal; Holland.
36.5°	France.

2. Dissociation of hydrogen dioxide into water and oxygen, which latter then exerts a direct oxidizing action, resulting in the formation of the following: acetic peroxide; acetaldehyde and acetaldehyde peroxide; and eventually acetic acid. The formation of acetic peroxide would facilitate a series of oxidations, and by its hydrolysis alone, acetic and peracetic acids would be formed. The peracetic acid would then become converted into acetic acid and hydrogen dioxide; therefore, it is reasonable to conclude that a continuous cycle of changes occurs in the ether during its oxidation and that such changes result in the simultaneous formation and occurrence of peroxidized compounds, intermediate (aldehyde) and ultimate (acetic acid) resultants.

When anhydrous ether is exposed to the action of atmospheric oxygen during improper storage, there is every reason for the conclusion that peroxidation occurs; such action is similar to that which takes place when anhydrous ether is ozonized, but the process is much less active, being indirect. During storage under conditions which would be conducive to oxidation, the absolute exclusion of moisture is not attained. Changes occur similar to those which ensue in the presence of water, but of a much slower and much less intense nature.

Our experimental work seems to establish beyond any doubt the fact that ether of anæsthetic grade contains peroxidized compounds after exposure to varying temperature conditions and sunlight, in the presence of atmospheric oxygen, for considerable periods of time, especially when it is stored in colorless glass vessels, or in badly stoppered tin containers.

Acetaldehyde, the presence of which may account for some of the observations made in practice, is one of the impurities most likely to be generated by exposing partially filled containers to varying atmospheric conditions for continued periods of time. Ether should not be stored in glass vessels for any length of time without being tested for oxidation products before use; and the tin containers should be of such capacity that they need not be opened without being emptied when the ether is employed for anæsthetic purposes. The sealing of tin containers will be referred to later.

With regard to the acidity of the various anæsthetic ethers on the American market, it may be said that none that we have examined contained acids (sulphurous, sulphuric, acetic) in what may be termed injurious amounts, since the amount present never exceeded 0.002 Gm. of acetic acid per 100 c.c. of the sample in any case. The degree of acidity is liable to vary more or less in both directions in short intervals during storage in glass vessels, just as in the case of the oxidation of ether itself. The variations in acidity—theoretical, but not sensible in general—may be due to differences between the rapidity of the oxidation and the saturation of the acids by the bases of the glass. In fact, it should be mentioned here that the nature of the ether container is of vast importance in the light of the oxidation changes which are possible. The extent of the oxidation—or, for that matter, any oxidation at all—is dependent upon the quality of the glass used in bottles for storing ether; and in the case of metallic containers, in view of some recent researches, it is probable that all metals which show anomalous anodic conductivity are likely to develop free hydrogen dioxide in contact with water and oxygen. The presence of such metals should, therefore, be guarded against.

Since it is highly important that ether intended for anæsthetic purposes should be carefully manufactured and properly stored, as prolonged exposure to light and air greatly affect the results of etherization, causing coughing, suffocation, and even dangerous after-effects, such ether should always be tested for peroxides and aldehyde, and the presence of the latter should be rigorously guarded against, or the ether, if so contaminated, should be administered by a method which eliminates these impurities before it is introduced into the animal system.

We have made an examination as to the value of all proposed tests for the impurities in ethyl ether and devised several new and superior ones. A scheme for examination has been worked out and is now available in the literature.[9]

CHLOROFORM.

Liebig prepared chloroform from chloral. Soubeiran treated alcohol with "bleaching powder." Schering generated his "bleach" in the presence of alcohol by electrolysis. Then "methylated spirit" was used, whereby so-called "methylated chloroform" was obtained. Liebig also obtained chloroform by the action of "chloride of lime" upon acetone. Böttger and others used acetates (1848), and then chlorine was liberated in acetone by electrolysis. This process is used extensively in this country now. Methane of natural gas has been burned in chlorine, but this process has not proved successful commercially so far, although "gas chloroform" is spoken of by some in a wise way. Carbon tetrachloride, made by chlorinating carbon disulphide, is being reduced by the process of Smith to produce much chloroform in this country at present. "Chloral Chloroform" is imported in small quantities.

From the variety of "ausgangs-material" and different methods used, it is quite evident that crude chloroform may contain a wide range of impurities, which may vary not only with the materials used, but the conditions of manufacture. Alcohol has been removed from chloroform by washing with water, the chloroform being subsequently dried over calcium chloride. Potassium hydroxide has been used to remove excess chlorine and acids. Manganese dioxide has been used to remove sulphur dioxide. Chloroform has been treated with concentrated sulphuric acid until the acid was no longer colored, and then the vapors of chloroform have been passed through towers of crystallized sodium carbonate; rectification has followed. To remove special impurities or decomposition products of the chloroform itself, chloroform has been treated with lead dioxide; with potassium permanganate, or with dilute sodium thiosulphate; or it has been distilled over 2 per cent. paraffin or poppy oil.

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[9] *J. Ind. and Eng. Chem.* iii, 395.

"Chloroform Anschütz" is obtained by distilling from crystals of salicylid-chloroform ($C_{28}H_{16}O_8.2CHCl_3$). "Chloroform Pictet" is made by chilling chloroform to — 80° C., filtering off the solids produced, and then lowering the temperature to — 82° C. and drawing off the liquid impurities. The frozen chloroform is then fractioned, the intermediate 80 per cent. of the distillate being taken.

TABLE V.

DETERMINATIONS OF THE SPECIFIC GRAVITY OF CHLOROFORM.

0°	1.52523, 1.52657
11.8°	1.5039
12°	1.496, 1.512
15°	1.485, 1.4946, 1.4905, 1.4976, 1.5066, 1.5107, 1.4989, 1.4980, 1.500, 1.50027, 1.50085, 1.49887 (Baskerville and Hamor).
15.5°	1.500
16.5°	1.472
17°	1.491, 1.507
18°	1.48
18.58°	1.48978
25°	1.48432, 1.48492
29°	1.49089
35.86°	1.45695
60.8°	1.4081
61.2°	1.40877
63°	1.3954, 1.4018, 1.408114

The specific gravity values of chloroform have been determined by different workers [10] as shown in Table V.

In the course an investigation of the decomposition of chloroform, we prepared pure chloroform. This possessed a density of 1.49887 at 15/4° C. (average of six determinations), a result in close agreement with the values of Thorpe and

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[10] Chas. Baskerville and W. A. Hamor, *J. Ind. and Eng Chem.*, iii.

Timmermans. This value may be taken as the correct specific gravity at the temperature noted.

The anæsthetic chloroform on the American market varies in specific gravity from 1.4730 to 1.4827 at 25/25°, usually in close proximity to 1.476, the minimum density permitted by the *Pharmacopœia*. The samples of chloroform of German manufacture examined varied in specific gravity from 1.487 to 1.492 at 15/15°, although one sample possessed a density of 1.497 at this temperature. Since the correct specific gravity of chloroform is 1.49887 at 15/4°, those officials requiring chloroform of lower density—that is, anæsthetic chloroform—allow the addition of alcohol, and consequently the presence of small amounts of water; the permissible addition usually varies from 0.25 to 1 per cent.

Specific gravity determinations are not to be regarded as criteria of purity beyond indicating the amount of alcohol in chloroform.

The chloroform constants according to various editions of the United States *Pharmacopœia* are as follows:

Date.	Density at 15°	Boiling point.
1851	1.49	142° F.
1869	1.490–1.494	140° F.
1873	1.480	142° F.
1882	1.485–1.490	60–61° C.
1893	Not below 1.490	60–61° C.

The specific gravities of the chloroform recognized as official by the pharmacopœias of various countries are given in Table VI.

The boiling points of anæsthetic chloroform recognized as official by the various pharmacopœias are shown in Table VIII.

In general, it may be said that no specific directions are given in the pharmacopœias for the determination of the boiling point and the influence of the variables (alcohol and water in particular) has not received enough attention. Opinions are divided as to the value of the determination as a criterion of the purity of anæsthetic chloroform. In the writer's opinion, it is of no value without a knowledge of the content of alcohol and water. In making a careful fractionation of 500 Gm. of anæsthetic chloroform made from acetone, containing 0.5 per cent. alcohol and 0.026 per cent. water, but otherwise pure, the temperature

TABLE VI.

DENSITIES ACCORDING TO VARIOUS PHARMACOPŒIAS.

1.480	Spain; Portugal; Mexico.
1.489	Switzerland.
1.490	Greece.
1.497	Chili.
1.498	France.
1.500	Romania.
1.485–1.489	Germany; Denmark, Hungary; Norway; Sweden; Finland.
1.485–1.490	Belgium.
1.485–1.495	Japan.
1.485–1.500	Austria.
1.490–1.495	Italy.
1.490–1.495	Great Britain.
1.498–1.500	Holland.
1.490–1.500	Russia.
Not below 1.476 at 25°	United States.

TABLE VII.

BOILING POINTS OF CHLOROFORM DETERMINED BY DIFFERENT SAVANTS.

Year.	Observer.	Temperature.
1883	Schiff	60.9° at 754.3 mm.
1884	Perkin	62.0° at 760 mm.
1885	Bauer	61.0° at 760 mm.
1899	Thayer	61.6° at 760 mm. 61.64° at 760 mm.
1899	Pettit	61.97° at 760 mm.
1904	Wade and Finnemore	61.15° at 760 mm.
1911	The Author	61.20° at 760 mm.

TABLE VIII.

CHLOROFORM BOILING POINTS ACCORDING TO VARIOUS PHARMACOPŒIAS.

59.5–61.5°	Sweden.
60°	Italy.
60.8°	Spain; France: Chili; Romania.
61°	Mexico; Greece.
60°–61°	United States; Russia.
60°–62°	Great Britain; Germany; Austria; Switzerland; Belgium; Denmark; Norway; Japan; Finland.
61.3°	Holland.
61°–62°	Hungary.

rose at once to + 55.5° C., at which point part of the alcohol and water with some chloroform passed over, the remainder going over between + 59.4° and + 61°. The following fractions were obtained:

Temperatures.	Weight of fraction.
55.5–59.4°	10 Gm.
59.4–61.0°	177 Gm.
61.0–61.2°	300 Gm.
Above 61.2°	13 Gm.

The influence of alcohol and water, separately or together, on the boiling point of chloroform, may be seen from Table IX.

There has been not a little diversity of opinion among chemists as to the nature and products of the decomposition of chloroform, especially the changes which chloroform undergoes upon exposure to air; in fact, this discordance dates from the introduction of chloroform as an anæsthetic and prevails to-day. This condition is ascribable to the many influencing factors occasioned by the degree of purity of the chloroform under examination, the extent and nature of the exposure; but is principally due to the failure to consider, and therefrom to correctly interpret, the rôle of the general variable, alcohol, and with it the accompanying moisture.

TABLE IX.

BOILING POINTS OF MIXTURES OF CHLOROFORM, ALCOHOL AND WATER.

Constituents.	Per cent. chloroform.	Boiling point.
1. Chloroform-alcohol-water	92.5	55.5°
2. Chloroform-water	97.5	56.1°
3. Chloroform-alcohol	93.0	59.4°
4. Chloroform	100.0	61.20°
5. Alcohol-water (95.5 per cent. alcohol)		78.15°
6. Alcohol		78.3°
7. Water		100.00°

The products of the decomposition of "pure" chloroform, according to various investigators, may be thus summarized:

Chlorine; hydrochloric acid: Morson; Maisch; and Hager.

Carbonyl chloride: Rump; Regnault.

Carbonyl chloride; hydrochloric acid: Stark; Ramsay; Schoorl and Van den Berg; and Dott.

Carbonyl chloride; chlorine: Brown; Schacht and Biltz; and Adrian.

The formation of carbonyl chloride is alone definitely agreed upon.

The decomposition of chloroform has been universally conceded to be an oxidation process. It is generally accepted that chloroform is unaffected by light alone, and that light, although it accelerates oxidation, is not a necessary factor in the process (Hager; Rump; Brown; Schoorl and Van den Berg); however, several investigators appear to have inclined to the view that light favors decomposition (Regnault; Dott).

With regard to the changes which occur in anæsthetic chloroform during exposure to air and light, there also exists a decided diversity of opinion, principally owing to the fact that no examinations were made during the course of the various investigations, so far as we are aware, for the presence of the oxidation products of alcohol in such chloroform. The whole subject required investigation, and accordingly an experimental study of the decomposition of both pure and anæsthetic chloroform was carried out. It was also hoped to throw light on, if not fully explain, the rôle of alcohol[11] and other substances in the so-called preservation of chloroform, a satisfactory explanation of which has been wanting.

Various samples, some twenty-three in all, of both pure chloroform[12] and chloroform containing the usual pharmacopœial amounts of alcohol and water, were exposed, in well-stoppered [13] containers of various sizes, and containing varying amounts of the samples, and of both colorless and anactinic glass, such as are customarily used in the trade, for different

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[11] The amounts of alcohol stated as permissible in the various official chloroforms intended for anæsthetic purposes are as follows:

Belgium	1.0 per cent.
Denmark	1.0 per cent.
Sweden	0.5–1.0 per cent.
United States	0.6–1.0 per cent.
France	0.005 part by weight.
Italy	0.5 per cent.
Switzerland	1.0 per cent. absolute.

[12] This chloroform was prepared according to the method of the authors, and was absolutely pure.

[13] No cork stoppers unprotected by metal caps were employed. In the experiments on pure chloroform, glass-stoppered bottles were solely used.

periods of time, but at room temperature (20° C.), from September to May, inside of a window having direct southern exposure. The conditions were extreme, but nevertheless were similar to those obtaining in many pharmacies and hospitals.

The anæsthetic chloroform used was examined prior to the experiments, and only such chloroform as was found to be free from all impurities was used. However, an amount of water equivalent, on the average, to 5.1 per cent. by volume of the alcohol present was permitted.[14] Thus each sample was of pharmacopœial grade.

The tests applied for the detection of the oxidation products of chloroform and alcohol were those previously proved out in our work. Quantitative determinations of the impurities developed were made when possible.

The experimental results warranted the following conclusions:

1. The products of the oxidation of *pure* chloroform are carbonyl chloride and hydrochloric acid, which come about according to the reactions:

$$CHCl_3 + H_2O + O_2 = COCl_2 + HCl + H_2O_2;$$
$$CHCl_3 + H_2O_2 = COCl_2 + HCl + H_2O.$$

We are convinced that oxidation will not occur if water be excluded, and the absolute exclusion of moisture appears to be impossible in practice. Hydrogen dioxide is formed, although we have been unable to detect it in chloroform undergoing oxidation and therefore conclude that its existence is ephemeral, and oxidation of the chloroform continues throughout the period of the exposure. The rôle of the water is that of a true chemical catalyst. The decomposition of pure chloroform is accelerated by light, as was shown by a comparison of the results obtained in the experiments wherein colorless glass was used with those in which anactinic glass containers were employed. Carbonyl chloride is formed with increased readiness in the presence of acids.[15]

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[14] The alcohol content of the anæsthetic chloroform used was determined quantitatively by the method of Nicloux.

[15] Cf. Lowry and Magson, *Trans. Chem. Soc.*, xciii, 121, who observed that the formation of carbonyl chloride is evidently accelerated by the presence of acids.

The extent of the oxidation is dependent upon the nature of the container, the amount of air present, the purity of the sample, and the intensity of the light to which it is exposed. With light alone, when no air is present, no decomposition occurs for ordinary periods of exposure; and in cases where there is air contact alone, and no exposure to light, the oxidation is slow.

Free chlorine can only result from the photochemical decomposition of carbonyl chloride.[16]

$$COCl_2 \rightleftarrows CO + Cl_2.$$

It is likely that in the cases where "chlorine" was identified as an indication of incipient alteration of chloroform, hydrogen dioxide was the cause of the reactions observed. No chlorine was found when containers of anactinic glass were used; and when chlorine is detected, it must be the result of a secondary reaction.

2. The products of the oxidation of *anæsthetic* chloroform are primarily the oxidation products of alcohol, and no decomposition of chloroform itself occurs while the oxidation of alcohol proceeds. When the oxidation of alcohol reaches a maximum, decomposition of the chloroform goes on as in the case of pure chloroform, with the exception that chlorinated derivatives of the oxidation products of alcohol may result. The decomposition of the chloroform itself is retarded, even prevented, so long as oxidation of the alcohol proceeds, and the retardation is consequently dependent upon the amount of alcohol present. The extent of the oxidation is subject to the conditions referred to in the oxidation of pure chloroform. It is important to note, however, that anæsthetic chloroform always contains water, the usual amount being about 0.05 per cent. by volume, according to our experiences.

At the inception of this investigation, it was considered possible that the instability of chloroform of all grades might be due to the presence of some catalytic agent, the removal of which would lead to beneficial results, as has been found in the case of sodium hypochlorite,[17] for example. We have arrived at the conclusion that, given proper purification, the chloroform prepared from chloral hydrate, alcohol, acetone, or carbon tetrachloride, is in all cases identical from an anæsthetic point of view and in decomposition products, as we know they are identical in chemical composition. But it was ascertained that the oxidation of alcohol is accelerated by the presence of oxidizable bodies in solution and that foreign organic substances have a detrimental influence upon chloroform—which shows the necessity of having anæsthetic chloroform of a high degree of purity, from whatever source it may be prepared.

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[16] Coehn and Becker, *Ber.*, xliii, 130; and Weigert, *Ann. Physik.*, (4), xxiv, 55. The influence of light on the reversible reaction, $CO + Cl_2 \rightleftarrows COCl_2$, is purely catalytic.

This leads to the rôle played by ethyl alcohol in the preservation of chloroform, for alcohol does prevent the decomposition of chloroform, as first suggested by Squibb, in 1857, and later (1863) by Brown, independently.

Those who have investigated the part played by alcohol in preserving chloroform up to the present time have held that either chloroform decomposes in the presence of alcohol and that the alcohol takes care of the decomposition products, or the alcohol acts as a "catalytic retarding agent" (Stadlmayr).

The preservative action of alcohol is due to the combination of the retarder with certain of the reacting substances; and any substance soluble in chloroform and readily oxidizable will exert an inhibitory effect on the oxidation of chloroform itself, for example, sulphur and many other substances.[18] All compounds which have been found to serve as preservatives of chloroform are reducing agents, and the effect is only due to their capacity for oxidation. In the case of alcohol, inhibition develops with oxidation and retardation results until the oxidation of the inhibitor reaches a maximum. Thus, when chloroform is "preserved" with alcohol, the preservative is gradually consumed and is eventually totally destroyed, after which the decomposition of the chloroform itself proceeds as in the case of pure chloroform, with the exception that chlorinated derivatives of the oxidation products of alcohol may result.

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[17] The decomposition of commercial hypochlorite of soda is very largely due to the presence of small quantities of iron as ferrate in the liquor. Musspratt and Smith, *J. Soc. Chem. Ind.* (1898), xvii, 1096; (1899), xviii, 210.

[18] Baskerville and Hamor, *loc. cit.*

The Storage of Anæsthetic Chloroform.—Anæsthetic chloroform should preferably be furnished in vials or bottles of high grade anactinic glass,[19] containing about the quantity sufficient for one narcosis, and at the most not more than can be used within several days. If, for any particular reason, chloroform is ordered in a large container, it is advisable, immediately after opening it, to subdivide the entire remaining contents into two-ounce bottles, taking care to fill the small bottles completely. It is important to see that the bottles are completely free from water, and empty bottles should not be refilled without thoroughly cleansing and drying them. In no case should chloroform be gradually withdrawn in small quantities from large bottles or carboys. When it is found necessary to store anæsthetic chloroform, it should always be kept in a cool, dark place, in well-filled, or, better still, completely filled, tightly stoppered bottles of anactinic glass.

The condition of officinal chloroform which may be transported across the ocean and continent, or kept at sea for variable lengths of time, where it would be subjected to constant agitation, has been investigated. Anæsthetic chloroform in unopened, brown glass bottles were subjected to intermittent agitation for over 200 hours in a Spiegelberg shaking apparatus, and it was learned from four samples so treated that it is desirable to prevent the presence of air, *i.e.,* oxygen, being in association with this anæsthetic when it is to be shipped in the usual manner. Mouneyrat devised a method of displacing air by nitrogen, even making a nitrogen siphon of chloroform.

The keeping qualities of anæsthetic chloroform may be seriously affected by the character of containers. The question of keeping anæsthetic chloroform in tin containers has been a much agitated one in the Federal War Department, and within the last ten years this Department has decided in favor of the tin container.

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[19] The glass should show no alkaline reaction when the bottle is filled with distilled water containing several drops of phenolphthalein solution and heated at 100° C. for six hours. On the action of alkalies on chloroform, see Berthelot, *Bull. soc. chim.,* (2), xxix, 4; Andre, *Compt. rend.,* cii, 553; de St. Martin, *ibid.,* cvi, 492; and Mossler, *Monatsh.,* xxix, 573. It appears to be established that potassium hydroxide in alcoholic solution will slowly decompose chloroform.

The opinion of the author is that glass containers are more conducive to purity for several reasons: First, in cleaning the vessels any foreign matters present may be readily observed and the bottles properly cleaned. Second, in the case of tins, some of the flux used in soldering may be introduced and thus impart an acid reaction to the chloroform. Hydrochloric acid accelerates the decomposition of chloroform. The introduction of this flux is also a problem in ether manufacture which requires the utmost care.

Since it has been stated that spirit containing 95 to 96 per cent. by volume of ethyl alcohol is perfectly indifferent to tin, and tin and tinned metals are absolutely unattacked by 90 per cent. denatured spirit, the tinned metals only being corroded where the tin layer is broken,[20] one would conclude that acid-free chloroform,[21] containing the usual amounts of alcohol and water, would also be without action on tin, providing it is stored in tin containers, having no broken or scratched surface, very carefully capped, and with a minimum amount of air. In order to determine this, a five-pound sample of chloroform containing 0.84 per cent. by volume of absolute alcohol and approximately 0.05 per cent. of water, which had been stored in a tin container, sealed, for sixteen months, was examined for the presence of tin. This sample left a residue non-volatile at 100° C., amounting to 0.0220 Gm. per litre, but none remained upon ignition and no tin could be detected in the sample. The examination of a sample of anæsthetic chloroform which had been kept in a sealed tin for six years also showed that no tin had been dissolved. In both cases, however, oxidation of the alcohol present had occurred, although no decomposition products of chloroform were present.

Third, we have been informed by H. H. Dow [22] that he has "demonstrated that moist chloroform in the presence of a metal will slowly form traces of CH_2Cl_2 and . . . that it is possible to distil pure, dry chloroform in a metal container and produce a decomposition as shown by the following formula:

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[20] Heinzelmann, *Z. Spiritusind.*, xxvii, 339. Malmejac, however (*J. Pharm. Chim.*, 1901, xiii, 169) found that a small amount of tin goes into solution in 95° alcohol after six months.

[21] On the action of hydrochloric acid in chloroform on tin, see Patten, *J. Physical Chem.*, vii, 161, who found that the dry solutions act upon the metal less violently than upon zinc or aluminium, but more violently than on lead.

[22] Private communication.

$$4CHCl_3 + 2Cu = C_2Cl_6 + 2CH_2Cl_2 + Cu_2Cl_2.$$

This reaction, however, takes place so slowly that it would never be noticed except in the handling of a material on which superlative efforts have been expended for years in order to get the last extreme of purity." Moreover, " all chloroform contains traces of CH_2Cl_2." In this connection, it should also be mentioned that it is probable that all metals which show anomalous anodic conductivity are likely to develop free hydrogen dioxide in contact with water and oxygen;[23] in the author's opinion, the presence of such metals should therefore be guarded against in the selection of a container for anæsthetic chloroform.[24]

The Pharmacopœia of the United States formerly required the use of " glass-stoppered " bottles, but subsequently changed this to " well-stoppered " bottles, thus allowing the use of cork stoppers, a practice which has become general in this country.[25]

The objections which have been urged against the employment of cork stoppers are two in number: First, the chloroform penetrates the cork after some time, especially during the agitation incidental to shipment, causing shrinkage and perhaps consequent leakage.

Allain [26] and Masson [27] have recommended that when chloroform is kept in cork-stoppered bottles, a lute of " bichromate gelatin " should be used to prevent leakage. This is unnecessary when a proper stopper is used and the employment of lutings on the stoppers has led to differences between the manufacturer and consumer in the past. Only one of the many samples of anæsthetic chloroform examined by the author was contained in a bottle having a luted cork stopper, and in this case, considerable organic matter had been taken up, and, as a result, the chloroform failed to comply with the important sulphuric acid test or confused its interpretation.

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[23] All of the manufacturers of chloroform in this country use brown glass (" anactinic ") bottles. Of the eight different makes of German chloroform examined by the authors, only two were contained in colorless bottles.

[24] Barnes and Shearer, *J. Physical Chem.*, xii, 155, 468.

[25] In Germany, however, glass-stoppered bottles are used by prominent producers of anæsthetic chloroform (Kahlbaum; de Haen; Merck; A.-G. für Anilin-Fabrikation).

[26] *J. Pharm. Chim.*, (3), ix, 571.

[27] *Ibid.*, (6), ix, 568.

The second objection is that organic matter is extracted from the cork and the chloroform fails when the sulphuric acid test is applied. To obviate these difficulties, certain manufacturers of chloroform have adopted the plan of covering the bottom of the corks with tin foil, a procedure which so far has been found to be satisfactory, but which may be open to some of the objections to tin containers. Other manufacturers use a paper or parchment covering, and still others select only the best corks and extract them thoroughly with chloroform before use.

The impurities of anæsthetic chloroform, so-called "organic impurities," are traceable to the materials used in the making, method of manufacturing, subsequent purification, manipulation before marketing, which may be grouped into one class (A), and those developed with different conditions of storage (Class B).

These impurities, even though some may not be of much importance from a physiological stand-point, must still be given attention, since an impure chloroform is more likely to become altered through oxidation during storage, notwithstanding the fact that pure ethyl alcohol has been added. So far as we have been able to learn, the adulteration of anæsthetic chloroform is not practised now, and crude chloroform is no longer sold as chloroform of anæsthetic grade.

In the first class (A) we have:

Excess water;
Excess alcohol;
Acetone;
Methyl alcohol;
Carbon tetrachloride;
Carbon dichloride (C_2Cl_4), carbon trichloride (C_2Cl_6), etc.;
Aldehydes;
Amyl, propyl, and butyl alcohols, and compounds;
Ether[28];
Acids (sulphuric, hydrochloric, acetic);
Metallic chlorides;
Ethyl chloride;

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[28] From 1865–1875 ether was considered as one of the general contaminants of chloroform.

Ethylene chloride;
Ethylidene chloride[29];
Ethyl acetate;
Oils ("empyreumatic," "pyrogenous," "chlorinated");
Fixed and extractive matter.

The possible impurities under the head of Class B are as follows:

Acetaldehyde;
Acetic acid;
Carbonyl chloride;
Hydrochloric acid;
Hydrogen dioxide;
Chlorine;
Chlorinated derivatives of alcohol oxidation products.

You are spared a discussion of the numerous tests for these substances, as that discussion would of necessity involve much detail and be of interest mainly to the analytical chemist. Suffice it to say that in our laboratory we have studied every test we have been able to find in the literature and have been forced to devise new ones in some cases, while in others, we are unable to make any recommendations at all as yet. Two illustrations may prove of interest. Paraffin oil, sp. gr. 0.88, may be used to discriminate between 0.08 and 0.09 per cent. of water in chloroform, but it does not show the presence of a smaller amount. We are not aware of any test having been devised to show the presence of less than 0.05 per cent. of water in chloroform, until we found that crystals of calcium carbide would answer most satisfactorily.

Carbon tetrachloride boils at + 78.1° C. and has a specific gravity of 1.63; chloroform boils at + 61.2° C. and has a specific gravity of 1.4989. A binary mixture containing 7.8 per cent. carbon tetrachloride boils at + 62° C. From what has been said of the presence of the variables, alcohol and water, in anæsthetic chloroform and their influence upon the physical properties of chloroform, it will be quite evident that determinations of these physical constants can be of little real value, and their application in general practice, even in well-equipped laboratories, is quite out of the question. All our efforts to secure a method applicable on a laboratory scale to detect small amounts of carbon tetrachloride in chloroform have been unsuccessful. To be sure carbon tetrachloride possesses anæsthetic properties, but it must exert its own specific physiological effect and the anæsthetist should know the drug he uses.

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[29] About 1880 ethylidene chloride was regarded as a general impurity of chloroform.

Among the anæsthetic mixtures, the combination of chloroform vapor with oxygen was used shortly after the introduction of chloroform as an anæsthetic, and it has recently been reintroduced into practice. Hence it was important to investigate the changes which anæsthetic chloroform undergoes when a current of oxygen is conducted through it. Dr. J. T. Gwathmey[30] has recently stated that oxygen increases the value of all inhalation anæsthetics as regards life.

Several experiments were carried out in order to determine whether the passage of a current of oxygen through anæsthetic chloroform brings about decomposition of the anæsthetic. Anæsthetic chloroforms containing 0.56 to 1.0 per cent. of alcohol and 0.03 to 0.05 per cent. water were used. The conditions were such, except that the temperature was about + 20° C., as obtain during administration by the Gwathmey method, his apparatus being used. The oxygen was allowed to flow at such rates through 3½ to 4 ounces of the anæsthetic that about one-half remained in the vaporizer after 3½ to 10½ hours. In one experiment the chloroform vapor was passed through water as is Dr. Gwathmey's practice, and subsequently condensed. The examination of the residue and condensed chloroform showed the following:

Acidity (acetic acid):

Chloroform used	none.
Residue in container	0.00015 g. in 100 c.c.
Condensed chloroform	none.

Sulphuric acid test:

Chloroform used	negative.
Residue in container	marked reaction.
Condensed chloroform	negative.

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[30] The writer has been collaborating with Dr. Gwathmey, who has directed the clinical observations.

Therefore it was concluded that the oxidation products of alcohol are not carried over when the chloroform-oxygen stream is conducted through water, and that these are concentrated in the residue. By this method of administration the patient is protected from the objectionable decomposition products even if they have developed. Furthermore, the vapors of the anæsthetic so applied are saturated with water, hence cannot exert that dessicating effect upon the mucous membrane they would if not moisture laden.

OXYGEN.

As animadverted, ninety-four years after the discovery of nitrous oxide and oxygen by Priestley, they were first used in combination for anæsthetic purposes. Although Andrews published accounts of several cases in which, by mixing oxygen with nitrous oxide, he had obtained a more satisfactory form of anæsthesia than with nitrous oxide alone, his observations failed to attract the attention they deserved. Ten years later (1878) Paul Bert drew further attention to this form of anæsthesia. Hewitt [31] stated, previous to the completion of the work reported this evening, that the most recent and best development in modern anæsthetics is the combination of oxygen with nitrous oxide, whereby a non-asphyxial and safe form of anæsthesia may be produced. The results of a long series of experiments with various anæsthetics and different mixtures caused Gwathmey to say "Oxygen is indicated with every anæsthetic and at all times. The longer the anæsthesia, the more urgent is the call for oxygen by the blood." The importance of the purity of the oxygen used is apparent.

The alchemists [32] were probably acquainted with oxygen, perhaps also the Greeks [33] in the fifth century, and the Chinese,[34] long before Priestley's experiments. In 1630, Jean Rey [35] knew that certain metals, when heated, fix a portion of the air, and in

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[31] "Anæsthetics," The Macmillan Co.

[32] Bolton, *Am. Chem.*, iv, 170.

[33] Hoefer, *Histoire de la Chimie*, ii, 271.

[34] Duckwood, *Chem. News*, liii, 250.

[35] Jean Rey, *Essai sur la recherche de la cause pour la quelle l'estain et le plomb augmentent de poids quand on les calcine*, Bazas, 1630.

1674 Mayow[36] prepared oxygen from nitre. In 1771, Scheele[37] prepared the gas by heating several oxides including the black oxide of manganese, and at about the same time Cavendish[38] studied oxygen. To Priestley,[39] however, has been given the honor of discovering oxygen as a constituent of the air. Davy[40] and Lavoisier[41] later studied the preparation and nature of this gas.

At the present time there are the following methods of preparation and manufacture of oxygen:[42]

1. Heating chlorates;
2. Heating chlorates with various substances;
3. From hypochlorites and reaction of chlorine and water;
4. Heating sulphuric acid or sulphates;
5. Heating various solids and mixtures (MnO_2, CuB_4O_7, etc.);
6. Combustion of solid mixtures (chlorates with combustible material, alkaline peroxides with hydrated salts, etc.);
7. Reaction of peroxides (ozone) with water and aqueous solutions;
8. By electrolysis of water;
9. From the air by means of mercury, cuprous chloride, barium dioxide; manganates, plumbates, or living matter; dialysis or absorption; and
10. From liquid air.

Oxygen that is to be used in anæsthesia should contain at least 95 per cent. O_2 upon the dry basis. We found the pyrogallate method for the determination of oxygen the most convenient to employ and most satisfactory provided Hempel's[43] precautions to prevent the production of carbon monoxide are taken.

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[36] Rodwell, *Chem. News,* viii, 114.

[37] *Abhandlung von der Luft und dem Feuer,* Upsala u. Leipzig, 1777.

[38] *Trans. Roy. Soc.,* lvi, 432; lxxiv, 119, 170; lxxv, 372.

[39] *Trans. Roy. Soc.,* lxii, 147; lxv, 384; lxxiii, 398; lxxv, 279; lxxviii, 147, 313; lxxix, 7, 289. "Experiments and Observations on Different Kind of Air," London, 1775–1777, ii, 29; iii, 1; "Experiments and Observations Relating to Various Branches of Natural Philosophy," London, 1779, i, 192.

[40] *Trans. Roy. Soc.,* ci, 1.

[41] *Chem. J.* (Crell), iv. 440; v, 125, *Crell. Chem. Ann.* (1786), i, 33, 136; (1788), i, 354, 441, 528, 550, 552; ii, 55, 262, 431, 433; (1789), i, 145, 162, 260, 323; ii, 68, 145, 433; (1790), i, 69, 518; (1791), i, 71; (1803), i, 29.

[42] Baskerville and Stevenson, *J. Ind. and Eng. Chem.,* iii, No. 7.

[43] Hempel, "Gas Analysis," English translation by Dennis, 1906, p. 149.

The following sorts of matter may be suspected to exist in a cylinder of compressed oxygen:

1. Solids.
2. Liquids.
3. Gases and vapors:

    H_2O,
    Halogen acids, HNO_3, organic acids,
    O_3, NO_2, N_2O_3, SO_2,
    NH_3, organic bases,
    CO_2, halogens, oxides of chlorine,
    HCN, $(CN)_2$,
    PH_3, SbH_3, AsH_3, H_2S,
    H_2,
    CO, CH_4, organic matter,
    N_2, N_2O, rare gases of atmosphere.

For these impurities, some of which are harmless from a physiological point of view, a qualitative search should be made and then, whenever necessary, a quantitative determination. A systematic procedure was devised which need not be gone into here.

TABLE X.

No.	Source of oxygen.	O_2	H_2O	CO_2	H_2	Organic matter.	N_2, etc.	All other impurities.
1	$KClO_3 + MnO_2$	93.20	0.30	0.11	0	0	6.39	0
2	$KClO_3 + MnO_2$	98.31	0.14	present	0	0	1.54	0
3	$KClO_3 + MnO_2$	92.82	0.26	trace	0	0	6.92	0
4	$KClO_3 + MnO_2$	97.13	0.23	present	0	trace	2.63	0
5	Liquid air	96.10	0.15	0.01	0	0	3.74	0
6	Electrolysis	99.23	0.35	0.03	0.14	0	0.25	0
7	$Na_2O_2 + H_2O$	99.20	0.50	trace	0	0	0.30	0

Nitrogen and the "noble gases" may be determined by difference. It may be mentioned that no sensitive test is known for nitrous oxide.

Analyses, by our methods, of oxygen on the American market gave the results shown in Table X.

CONCLUSIONS.

I realize the danger of a mere chemist making an excursion into the field of medicine, but the extremely venturous one, if he has luck, may be swept by the rocks of which he is supposed to have little knowledge. But I have done enough in this field to make me take a theoretical plunge.

Modern studies in physiology have unquestionably shown that the animal body exists to a great extent by virtue of the chemical and physical changes going on within it. I know of no valid reason for assuming that these changes are essentially different from those we control in the laboratory. If we wish to duplicate or control a physical or chemical change in the laboratory, we must become familiar with all the factors and conditions. I know of only one class of such changes over which we have not as yet secured control, and in that class belong those processes which we term radio-active. I am not sure but that we even have indications pointing toward our control of these. One of the essential factors in controlling a chemical process is the quality of the material with which we are working. I cannot therefore but regard all published statistics as to the mortality attributed directly to the anæsthetic used as more or less worthless and that a large number of new cases must be observed to secure knowledge of the real physiological effect of the drug when carried into the system by the pulmonary route.

Impure foods, sophisticated intentionally or otherwise, may bring on disease. Impure drugs, concocted or otherwise, fail to produce the full effect planned by the physician in curing disease. I feel that the great lack of uniformity among the pharmacopœias of the world need not obtain, especially where the analytical methods are involved. True, as Remington has maintained, "the Pharmacopœia is a book of standards for medicines, and not for analytical chemists," yet the methods of standardizing should be comprehensive, accurate, and reliable, as well as rapid and as simple as possible. It is unquestionably impossible for every pharmacist to determine the quality of all his chemicals and drugs, but the druggist may easily apply simple tests to determine the purity of many, especially when these tests are decisive and simple. While the dispenser must largely depend upon the reliability of the manufacturer, he should, like the physician, be familiar with the changes which chemicals undergo when improperly stored, in order that he may not allow impurities to develop and may guard against their formation. What a step modern civilization would take, if the leading nations decided to put forth an international standard pharmacopœia, revised in full each decennium, with annual supplements!

Idiosyncrasy has served to account in large part for untoward after-effects of anæsthetics and certain disagreeable consequences, as nausea and interference with some of the normal organic functions, as glycosuria and albuminuria; these have often been regarded as natural results of anæsthesia and taken for granted. They may now be largely obviated, and in many cases entirely avoided, by the use of anæsthetics that are free from impurities, and by improved methods of administration. These statements are based upon clinical evidence.

The main objectionable constituent in ether is acetaldehyde. American official ethers call for three to four per cent. of ethyl alcohol in accordance with an old theory. Alcohol is practically never free from water, and in the presence of water and oxygen forms oxidation products. The speeds of the changes depend upon conditions. It has been shown that the administration of moist ether, free from aldehyde, at body temperature, is rarely followed by nausea (less than ten per cent.) and the usual strain upon the kidneys is not observed.

Chloroform was formerly made mainly from alcohol and contained many of the normal impurities of the alcohol used. These were not removed by the methods of purification practised, nor are they removable now, except by elaborate methods of purification. These impurities doubtless have had much to do with the feeling of uncertainty in administering chloroform. Pure chloroform undergoes decomposition when exposed under certain conditions, such, for example, as the manner in which anæsthetic chloroform is dispensed in some drug stores and hospitals. A suitable amount of alcohol prevents this decomposition, shunting the change in composition to itself; hence anæsthetic chloroform should contain ethyl alcohol. But the conditions of transportation and keeping of this chloroform should be such as to reduce the change of alcohol to aldehyde and acetic acid to the minimum.

Nitrous oxide, ether, and chloroform, each exerts its specific physiologic effect in producing anæsthesia without asphyxiation, provided the respiratory and cardiac functions are maintained approximately normal. This may be, and is being, accomplished by administering these gasified drugs with sufficient oxygen not to interfere seriously with the normal function of the hæmoglobin of carrying oxygen to the capillaries and by maintaining the usual concentration of carbon dioxide in, and providing its regular elimination from, the blood. Other factors involved are temperature and moisture. The anæsthetics are carried into the system at body temperature. This may be and is being accomplished by warming, and, in the case of ether and chloroform, by passing the vapor through heated water, which, at body temperature, not only removes the aldehyde, but saturates the gas with moisture (Gwathmey method). The osmotic action of the alveolar cells is thus affected only to the extent of the densities of the gases introduced into the lungs and not, as normally is the case, by temperature (always lower) and dessication as well. In other words, by the application of the principles of modern physical chemistry, the numerous variables are so reduced as to secure the real physiological effect of the particular anæsthetic drug after it enters the system. Nitrous oxide and oxygen may be used for prolonged anæsthesia and successfully for eighty per cent. of surgical cases; furthermore, ether and chloroform may be used with equal safety. The real, and no supposititious, idiosyncrasy of the patient may be mec. The expert anæsthetist may now not only make it possible for the surgeon to perform even greater miracles, but with more comfort to himself in his work, and with greater happiness and less discomfort to the patient.

Study of the Firefly. H. E. IVES. (*Phys. Rev.* xxxi, 637.)—In conjunction with Coblentz the author has described an investigation of the visible radiation from one variety of firefly (*Photinus pyralis*). This investigation differs from previous ones in the application of photography with color-sensitive plates. There are grounds for believing that the firefly's visible radiation is its total radiation. Experiments in the infra-red and the ultra-violet regions of the spectrum are described. The region from 0.2μ to 1.5μ was explored. The only radiation was in a narrow band at 0.57μ as previously found. The abdominal skin of the insect is proved to be transparent as far as 3. The light is apparently under the control of the insect and has none of the properties of true phosphorescence, but is due to some bio-chemical process, which there is no reason to suppose cannot be artificially produced by man.

THE DISTRIBUTION OF ORGANIC CONSTITUENTS IN SOILS.*

BY

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THERE have been isolated in these laboratories from soil organic matter since this work was begun a large number of compounds which are so varied in their composition, properties, and origin, that they may be said to cover fairly well the principal classes of compounds encountered in other lines of biochemistry, and therefore the knowledge in regard to the chemical relationship, origin and processes of change accumulated in such other lines can be directly applied to the understanding of the biochemical changes in soils and the constitution of soil organic matter. Previous to these investigations the only organic soil compounds mentioned are the mythical humic acid, ulmic acid, geic acid, crenic acid, apocrenic acid, humin and ulmin, all of which are shown to be complex mixtures and therefore non-existent.

Of the compounds thus far isolated, some contain only carbon and hydrogen; some carbon, hydrogen and oxygen; some carbon, hydrogen, oxygen and nitrogen; and some carbon, hydrogen, oxygen, nitrogen and phosphorus. These compounds fall into the following classes: (1) Paraffin hydrocarbons, represented by *hentriacontane;* (2) hydroxy-fatty acids represented by *a-monohydroxystearic acid* and *dihydroxystearic acid;* (3) organic acids of unknown constitution, represented by *agroceric acid, paraffinic acid, lignoceric acid,* and a number of *resin acids;* (4) esters and alcohols, represented by *agrosterol, phytosterol,*

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glycerides of fatty acids, and *resin esters;* (5) carbohydrates, represented by *pentosans* and *pentose sugars;* (6) hexone bases, represented by *histidine* and *arginine;* (7) pyrimidine derivatives, represented by *cytosine;* (8) purine bases, represented by *xanthine* and *hypoxanthine;* (9) pyridine derivatives, represented by *picoline carboxylic acid.*

In addition to those here mentioned, a number of others are already isolated and will be reported upon in later publications from this laboratory. The methods by which the above compounds were obtained and the full description of their chemical properties have been given elsewhere.[1] It is obvious that definite chemical information of this kind sheds much light upon the nature of soil organic matter and the processes going on in soils.

While the work along the lines already laid down in the isolation and identification of definite soil constituents was progressing, it seemed desirable, if not imperative, that an idea be gained of the extent to which such constituents are distributed in the soils of the United States. Having found a compound in one or two soils and devised a method for its isolation and identification, the question naturally arises: Is this compound peculiar to the soil from which it has been isolated or is it a general soil constituent? Does it appear in one and the same soil under all conditions or is it the result of special treatments or crop practices, etc.? It is obviously of the greatest importance to know under what soil conditions and in what soils or class of soils any particular compound or group of compounds exists in order that a true and comprehensive view of soil organic matter in these soils can be obtained. Such information is necessary for a well-balanced opinion on the nature of soil organic matter in general, and a thorough recognition of the abnormal characteristics of certain soil organic matter, that is, an ability to distinguish between what is normal and what is abnormal. A survey of a large number of soils from widely different regions was therefore made and a method devised for such examination.

This method consisted in the co-ordination of the separate methods used in isolating these compounds, so as to form a more or less rigid scheme of procedure for treating a relatively small amount of soil. The investigation methods naturally involved the use of very large amounts of soil, sometimes many hundred pounds, amounts too large for practical handling of so extensive a survey as was contemplated in this work. A further motive in formulating a rigid scheme of examination applied to a reasonably small sample of soil was to encourage such work among other investigators and students of soil with a view to extending this work over a larger area with a greatly increased force, to the end that a most comprehensive survey of the occurrence of such constituents in soil may be had and that exact knowledge of the nature of organic matter in soils might be increased and stimulated.

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[1] The Isolation of Harmful Organic Substances from Soils, by Oswald Schreiner and Edmund C. Shorey, *Bul. 53, Bureau of Soils,* U. S. Dept. Agric. (1909). The Chemical Nature of Soil Organic Matter, by Oswald Schreiner and Edmund C. Shorey, *Bul. 74, Bureau of Soils,* U. S. Dept. Agric. (1910).

The method employed in separating the compounds from the soils was essentially the same as that schematically represented in an earlier article in this JOURNAL.[2]

The results obtained on a number of samples from different localities by the application of the scheme outlined for the separation and identification of definite organic constituents in the soils are briefly given in the following paragraphs, the soils being grouped by States in which the samples were collected.

Maine.—Two samples of Orono clay from the vicinity of Oldtown, Me. In both samples were found pentosans, xanthine, and histidine and in one of the samples there was found in addition hypoxanthine.

Massachusetts.—Five samples from various parts of Boston Common, Boston, Mass. All of the samples showed the presence of pentosans, cytosine, hypoxanthine, and dihydroxystearic acid.

New York.—A sample of Volusia silt loam from Ontario County, N. Y., showed the presence in the surface soil of pentosans, cytosine, and histidine, and in the sample of subsoil there was found in addition to these compounds, hypoxanthine and dihydroxystearic acid.

A sample of Clyde loam from Orleans County, N. Y., contained in the surface soil pentosans, pentose sugars, histidine, cytosine, hypoxanthine and dihydroxystearic acid. The sample of subsoil showed in addition to the above compounds the presence of xanthine.

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[2] Schreiner and Shorey, JOURNAL OF THE FRANKLIN INSTITUTE, clxxi, 295 (1911). See especially Buls. 53, 74, and 80 of the Bureau of Soils for details.

The examination of a sample of muck soil from Orleans County, N. Y., showed in upper as well as lower layers of the muck the presence of pentosans, pentose sugars and histidine.

Pennsylvania.—A sample of Chester silt loam from the vicinity of Philadelphia, Pa., showed the presence of agroceric acid, pentosans, cytosine, arginine, xanthine, hypoxanthine, and dihydroxystearic acid.

A sample of Frankstown stony loam from Bedford County, Pa., contained in the surface soil pentosans, pentose sugars, histidine, and dihydroxystearic acid. The sample of subsoil, however, did not show the presence of dihydroxystearic acid, but did show the presence of the other compounds found in the surface soil.

Maryland.—In a sample of Elkton silt loam from the vicinity of Easton, Md., was found paraffinic acid, α-monohydroxystearic acid, pentosans, xanthine, and dihydroxystearic acid.

West Virginia.—Samples of both surface and subsoil of Dekalb silt loam from the vicinity of Ravenwood, W. Va., showed the presence of pentosans, pentose sugars, and histidine.

Kentucky.—A sample of Clarksville silt loam from the vicinity of Broadhead, Ky., on examination showed the presence of pentosans, pentose sugars, histidine and dihydroxystearic acid in the surface soil. In the subsoil the same compounds were found with the exception of dihydroxystearic acid.

North Carolina.—Investigations conducted on a peat soil from the region bordering Lake Mattamuskeet, N. C., revealed the presence of hentriacontane, lignoceric acid, phytosterol, several resin acids and resin esters.

Mississippi.—Investigation of a sample of Houston clay from Noxuluo County, Miss., showed it to contain histidine and arginine.

Texas.—A sample of Amarilla silt loam from Sherman County, Tex., showed the presence of pentosans, pentose sugars, and histidine in both surface and subsoil.

North Dakota.—A sample of Marshall clay from Fargo, N. D., under investigation, showed the presence of agrosterol, agroceric acid, xanthine and hypoxanthine.

In discussing the foregoing results it is not intended to dwell upon the origin of these substances in the soils examined. Suffice it, therefore, to merely recall here the facts more fully discussed in the earlier papers cited that soil organic matter consists of the debris of all plant and animal residues and that the individual constituents of soil organic matter comprise: (1) The accumulated substances not readily subject to change, existing in the same form as in the original plant or animal material, and, (2) all the decomposition products which would arise through any agency whatever from proteins, fats, lecithins, carbohydrates, alkaloids, terpenes and all other constituents of previous vegetation or animal occupation.

The above list comprises twenty-six samples from eleven States. From twenty-three of these soils pentosan was isolated; the other three had not been subjected to this examination. Two of these soils, however, indicate large amounts of pentosan to be present by the furfurol test, these two being the Marshall clay and the North Carolina peaty soil, as already reported.[3] It would appear, therefore, that pentosans are a general constituent of soil organic matter.

Pentose sugars are found in eleven of the soils. The test for pentose sugars was not made in the earlier samples examined, but it was found in all samples in which a test was made. It would appear, therefore, that pentose sugars or pentose-containing complexes, not pentosans, the chemistry of which will be reported on in later publications, are common constituents of soils.

Histidine is a primary decomposition product of protein material. Its occurrence in seventeen soils of the twenty-four examined for it indicates that this hexone base is a fairly common constituent of soils and shows, therefore, that the protein cleavage in the soil is similar to that brought about by chemical or other action in laboratory investigations. That histidine persists in the soil during and after protein decomposition may be due to the fact that it is more resistant to change than other compounds of similar nature and origin.

Arginine is a common cleavage product of protein, but has so far been found only in two soils and is probably not a soil constituent which persists for any length of time.

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[3] Shorey and Lathrop, *Jour. Amer. Chem. Soc.*, xxxii, 1680 (1910).

Cytosine is derived from the breaking down of nucleo-proteids and nucleic acids existing in all plant cells. The fact that it was found in ten soils out of twenty-three examined indicates that it may also be a rather common soil constituent and shows conclusively that the change of such constant complex plant constituents as nucleic acid progresses in the soil in the same manner as it does outside of the soil through chemical agencies better understood.

Xanthine and hypoxanthine exist in plants as such and like cytosine also result from the cleavage of nucleic acids and nucleo-proteids. They further result from other purine bases, guanine and adenine. It is, therefore, not possible to state at this time the direct source of the xanthine compounds in soils. It is probable that their occurrence will be traced to all these sources. Out of the twenty-four soils examined for these purine compounds, five contained xanthine and nine contained hypoxanthine, thus showing that these purine bases will probably be frequently encountered in soil work of this character. Some of the soils contained xanthine only and some hypoxanthine only. Four of the soils contained both. Hypoxanthine is more resistant to bacterial action and this may explain its more frequent occurrence in the soils tested.

Although agroceric acid, lignoceric acid, paraffinic acid, α-monohydroxystearic acid, as well as agrosterol, phytosterol, and hentriacontane are reported as having been found only once or twice in the above list of soils, no general statement covering their frequency or lack of frequency of occurrence is warranted.

Eleven out of the twenty-six soil samples contained dihydroxystearic acid; five of these, however, were from a single locality. An interesting fact which may prove to be important is that in only one case was dihydroxystearic acid found without either hypoxanthine or xanthine or both being found at the same time. In seven of the samples it was accompanied by hypoxanthine only, in two samples by hypoxanthine and xanthine and in one sample by xanthine only.

Many other soil samples have been examined for dihydroxystearic acid in these laboratories. Over eighty soil samples comprising soils from eighteen States, extending from Maine to Oregon and southward to Texas, of widely different origin, topography, texture, climate, drainage, and cropping, varying from soils of the highest productivity to soils incapable of producing profitable crops were thus examined with the result that dihydroxystearic acid was quite frequently encountered. The details of this investigation of soils for dihydroxystearic acid are reported elsewhere,[4] but for the sake of completeness, the general results should be here given.

One-third of all the soils examined showed the presence of dihydroxystearic acid. It was found in virgin soil as well as in soils under long cultivation; in soils continually cropped as well as in soils under permanent sod; in soils from the Atlantic coast; in soils from the Pacific coast; and in soils from the Gulf States. This compound is, therefore, a common soil constituent and is likely to be encountered in soils anywhere. Its formation or its accumulation is doubtless due to local conditions in any one section, but these local soil conditions are not confined to any region of the United States and probably not to any country or continent. The frequent occurrence of dihydroxystearic acid is of special interest and significance because of its known harmful properties to plants.[5]

When the soils examined are separated into good and poor soils, as based on field observations, their relationship with dihydroxystearic acid is rather striking. Among the good soils only two contained dihydroxystearic acid and they were of only moderate productivity. Among the poor soils the percentage of those containing this compound was fifty-one. Of the soils which had a record for infertility, the dihydroxystearic acid was found in each and every case.

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[4] *Bul. 80, Bureau of Soils,* U. S. Dept. Agric. 1911.

[5] Some Effects of a Harmful Organic Soil Constituent, by Oswald Schreiner and J. J. Skinner, *Bul. 70, Bureau of Soils,* U. S. Dept. Agric. (1910).

Soft-Toned Bells in China. Consul SAMUEL L. GRACEY in Daily Consular Report. (*Brass World,* vii, 203.)—The Chinese use large bells of their own make in many of their temples and monasteries. All through Japan and China the tone of these bells is very soft and smooth, due to the superior quality of the material used and to the absence of iron clappers. The bells are never swung, but are always suspended in a fixed frame, and are sounded by striking them on the outer edge with a wooden mallet. The result is a marvellous softness and mellowness of tone.

Liège Metal. Consul BARTLEY F. YOST, in Daily Consular Report. (*Brass World,* vii, 217.)—This "Liège Metal" is of special interest to aerial navigators both for "heavier than air" and "lighter than air" craft. It is said to be 40 per cent. lighter than aluminum and has a density of 1.762. It is grayish-white in color, reflecting rays analogous to those of poorly worked aluminum. Its composition is: Magnesium 99.3 per cent., sodium 0.21, zinc 0.44, iron 0.01, and aluminum 0.04 per cent.

Changes in the Velocity of Hydration of Cement. P. ROHLAND. (*Z. Chem. Ind. Kolloide,* viii, 251.)—Electrolytes change the velocity of hydration, and the effect is greater when they are added in the dissolved than in the solid state, and is approximately proportional to the concentration. Sodium carbonate, aluminum chloride, and potassium monosulphide accelerate the velocity while potassium bichromate, borax and sulphates (except aluminum sulphate and alum) retard it. The hardening process essentially consists in a coagulation of the hydrolytically separated hydroxides of silicon, aluminum and iron.

Harmful Influence of Sulphate from Commercial Salt on Firing of Stoneware. M. SCHMIDT. (*Sprechsaal.,* xliv, 264.)—The commercial salt used in salt glazing usually contains sulphates, which spoil the appearance of the finished ware, especially in an oxidizing atmosphere. The thin layer of salt-glaze becomes saturated with sulphates, which are either displaced by the silica of the body with evolution of gas and consequent bubbling of the surface, or else a separation of "galls" occurs. Sulphates are especially harmful, if salting begins before a full fire. The best way to avoid their action is to keep a reducing atmosphere in the kilns, till the last stage, when the fires are cleaned and air let through the grates. This reduces and eliminates the sulphates before the kiln reaches its highest temperature. But there is a risk of sacrificing the color of the body from the incomplete oxidation of the iron salts. The undecomposed sulphates are deposited on the walls of the kiln, take up water and percolate into the firebrick, where they separate out again and destroy the kiln. Sodium sulphate is more destructive than calcium sulphate.

NEW USES OF EXPLOSIVES IN AGRICULTURE.

BY

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Blasting Explosives have been used for a good many years for clearing new land of stumps and boulders and for cleaning up an occasional obstruction of this kind from land already under cultivation. Naturally the quantity of explosives required for this purpose has not been great because most of the larger farms started in the past twenty years are on prairie land where there are neither stumps nor boulders. An exception to this is found, however, in the Pacific Northwest where but little land is available for farms or orchards except that which is covered with stumps of great size. Here, land companies do the clearing on a large scale and use many carloads of dynamite every year.

The employment of explosives for clearing land cannot, however, be considered in any sense a new idea and farmers in all of those parts of this country where stumps or boulders have existed are well acquainted with its value for getting rid of them.

The new idea in farming to-day and one which bids fair to have remarkable and far-reaching results in relation to the growth and bearing of trees and plants is the deepening of the moisture-holding and vegetation-producing surface soil by using dynamite. The increasing demarkation between our wet and dry seasons, has made it necessary to adopt some artificial method of distributing more evenly to vegetation the moisture requisite to its proper development.

The first plan for overcoming uneven moisture distribution was a system of draining and irrigating. This seemed logical and effective because it disposed of the surplus water of the wet season and provided that which had been lacking in the dry season. There were, however, drawbacks to this plan, the principal ones being the prohibitive cost to private enterprise of systems of any considerable capacity, the impossibility of establishing them at any cost in certain localities and the forming of "alkali soil" by superirrigation in many places where draining and irrigating had been in effect for a few years.

Next, the soil-deepening theory was propounded. This was evidently a capital idea because it not only disposed of the surplus water of the wet season by making it possible for it to sink deep into the soil to be conserved there until it was drawn up when needed by the plants in the dry season, but it also provided open soil for plant roots to develop through, and made available to the plants a greatly increased quantity of the soil foods which they require. It appeared at first that deeper plowing would answer the purpose and it was strongly advocated by many agricultural authorities. The difficulty about deep plowing is that in many localities the subsoil is entirely unfitted for plant food until it has been exposed to sunlight, air and rain for a year or more. As the ordinary plow always turns the deepest soil that it reaches directly onto the surface, the depth of the surface soil could not be increased more than an inch or so each season without injuring the succeeding crops because the surface soil could not absorb a greater quantity of the subsoil and remain properly fertile. This was a very slow method of increasing the depth of the surface soil and was also limited because the ordinary plowing depth is only from five to eight inches with an occasional maximum of nine or ten inches, or twelve inches if the ground is plowed over the second time. The special subsoil plows go down fifteen to eighteen inches but they naturally require great power to operate.

With the drainage and irrigation idea almost prohibitive in cost and partly unsatisfactory in result, and the deep soil plowing plan slow and limited, the outlook for the establishment of new and maintenance of the old vegetation-producing areas in this country was not bright until the soil-blasting plan was suggested. It is not recorded just who first evolved this idea but it apparently originated in Kansas where in some places a very compact and well defined hard pan has prevented the satisfactory growing of crops. Samuel J. Crawford, once governor of Kansas, has been an advocate for some years of subsoil blasting, and it was his enthusiasm that led one of the large dynamite manufacturers to make an extensive study of the question a year ago which has resulted in demonstrations in the past six or eight months of its great value and practicability in many parts of the country.

The object when blasting subsoil is to shatter and break up a maximum area at a minimum cost without mixing it with the surface soil. To do this it is necessary to vary slightly the kind of explosive, size of charge and spacing and depth of bore holes to comply with the different subsoil conditions met with in different places.

The usual custom, however, is to space the holes either fifteen feet or twenty feet apart, make them two and a half to five feet deep and explode in them a quarter pound or a half pound of slow-acting dynamite of 15 per cent. to 25 per cent. strength. If the holes are twenty feet apart and four or five feet deep, best results may be given by a half pound of 25 per cent. dynamite in each hole. If on the other hand, the holes are only two and a half feet deep and fifteen feet apart a quarter of a pound of 15 per cent. dynamite may be sufficient. With the four factors of spacing of bore holes, depth of bore holes, weight of charge and strength of explosive it is possible to adjust this work so as to exactly suit almost every soil condition encountered and a little experience with close observation will determine just how any particular piece of land can be most economically blasted. If there is any uncertainty about this and a considerable area is to be blasted, it is a good plan to try a few experimental shots at different depths and distances and with different quantities of explosives, then dig a hole with pick and shovel midway between the holes blasted and observe the effect of the blast on the subsoil. If there is any evidence of fissure or breaking midway between the holes, the blast can be considered satisfactory and the remainder of the work carried out accordingly. As the standard size dynamite cartridge for this work is 1¼ x 8 inches, which weighs approximately a half pound, the charges consist of either a half cartridge or a whole one.

It has been the custom to make the holes for subsoil blasting either with a dirt auger or with a pointed bar which is driven to the required depth with a sledge or maul. It is probable, however, that as subsoil blasting becomes more general, these primitive tools will be replaced by either geared hand drills or power drills. A power drill operated by a gasoline engine is now in use in some of the Western States. As the dynamite should expend as much force as possible in the subsoil, the holes must be filled compactly with damp clay tamping from the top of the dynamite charge to the surface of the ground. It is generally the custom to explode the charges with blasting cap and fuse.

When this is done the fuses are cut so that from four to six inches will extend above the ground after the charge has been properly tamped in the hole. These are then lighted one after the other. A small torch is very effective for the purpose but unless a high wind is blowing, matches may be used. If the charges are properly gauged, located and tamped, there should be only a slight disturbance of the surface of the ground when they explode.

Sometimes the charges are exploded electrically with a blasting machine. Then electric fuses are used instead of fuse and blasting cap and from ten to a hundred and fifty charges are exploded simultaneously, depending on the capacity of the blasting machine. This method may be a little more effective but is also a little more expensive.

When a clearly defined clay hard pan from two to five feet thick is to be blasted, best results will usually be had if the charge of explosives is located about six inches above the bottom of the hard pan.

The cost of blasting subsoil, including explosives, blasting supplies and labor is between twelve dollars and twenty dollars an acre and this is not infrequently paid for by the increase in the first crop after the blasting has been done. As the beneficial effect of the blasting lasts many years it can be readily seen that it is an excellent investment.

The quantity of explosives required to blast an acre of ground with bore holes spaced at different intervals and loaded with different size charges is given in Table I.

TABLE I.

Distance between holes, feet.	No. of 1¼ x 8-inch cartridges in charge.	Approximate No. of pounds of dynamite per acre.
15	½	50
15	1	100
20	½	27½
20	1	55

Subsoil blasting is not only done on land producing cotton, cereals, small fruit, vegetables, etc., but has proven of great value in orchards. Here it helps to dig the hole for the new tree, makes ample room for roots to spread and provides a reservoir for conserving the moisture required to support the tree. After these orchards have begun bearing, and particularly in old orchards where the trees are beginning to fail, root cramping, "wet feet," wet rot and many other obstructions to their growth, are overcome by blasting between the trees or in some cases directly under them. Blasting between the trees is done in the same way as other subsoil blasting except that the holes should not be less than four feet deep and the method of spacing them is governed by the distance apart the trees stand. A charge of a quarter of a pound of 25 per cent. dynamite in each hole, is generally sufficient.

When the trees are planted on the "square system" and are fifteen to twenty feet apart, the holes should be located midway between the trees on diagonal lines, making one hole to each tree (Chart I). Trees planted on the "square system" twenty-five or thirty feet apart require the holes for blasting midway between them on the square lines or an average of two holes to the tree (Chart II). If the trees are more than twenty-five feet apart three holes should be put down on three sides of the tree, about ten to fifteen feet away from it, these holes being located at the points of an equilateral triangle with the tree in the centre (Chart III).

Explosives are now being employed very largely for digging ditches. In much of this ditching dynamite does the whole thing and neither pick, shovel nor ditching machine is used. Although ditching may be done almost entirely with dynamite under nearly any condition, it is particularly economical and effective in swampy clay ground and many ditches are now dug with dynamite in land of this character. To dig these ditches holes are punched with sharp bars at intervals of two feet along the line of the proposed ditch, to a depth six or eight inches less than the ditch is to be. These holes are not perpendicular, but at an angle of from 25° to 45° with the perpendicular, and all pointed toward that side of the ditch where the material excavated is to be thrown. All of the holes but the middle one are loaded with one cartridge (1¼ x 8 inches) of 50 per cent. or 60 per cent. nitroglycerin dynamite. The middle hole is loaded last with two or three cartridges of the same explosive, one of which has been primed with a section of waterproof fuse and a No. 6 blasting cap. It is not necessary to use tamping in any of the holes provided the ground is sufficiently swampy for water to cover the charge of explosives when it is in place in the bottom of the hole. The detonation of the charge in the middle

CHART I.

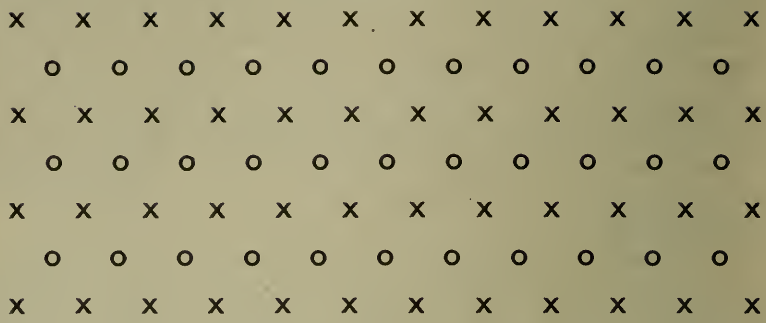

Diagram showing location of holes for blasting when trees are 15 feet to 20 feet apart. **X** = tree; **O** = hole for dynamite.

CHART II.

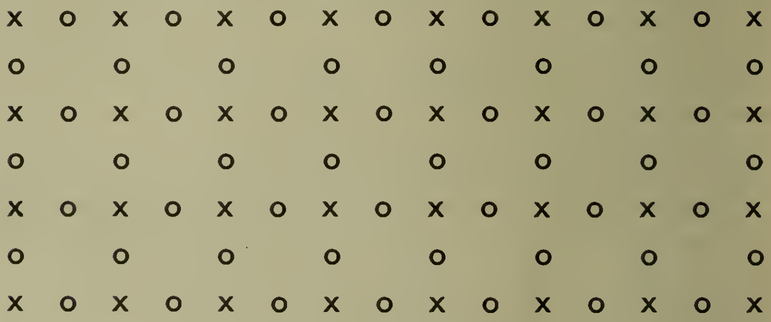

Diagram showing location of holes for blasting when trees are 25 feet to 30 feet apart. **X** = tree; **O** = hole for dynamite.

CHART III.

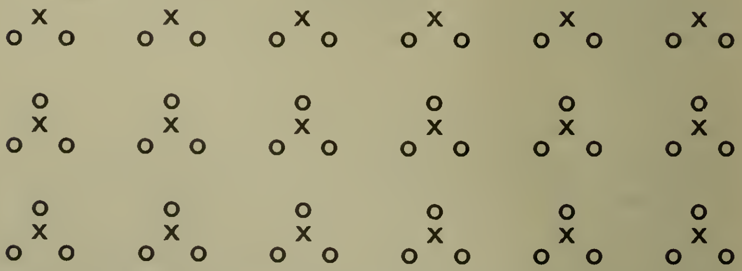

Diagram showing location of holes for blasting when trees are more than 30 feet apart. **X** = tree; **O** = hole for dynamite.

hole communicates to the adjacent charge in both directions and so on, almost instantaneously to either end of the row and a comparatively regular ditch about three feet wide at the bottom, five feet wide at the top and from three feet to five feet deep, according to the depth of the holes, is the result. The length of the ditch which can be blasted at one time is only limited by the time required to charge the holes. A mile or more may be blasted simultaneously provided enough men are punching and loading the holes to finish the work quickly, but nothing is gained by attempting to blast so much at once that the dynamite in holes first loaded will be kept under the water longer than an hour or so before blasting. The middle hole is always charged just before blasting so that the blasting cap and fuse will not remain under water longer than a few minutes. This work should be done in comparatively warm weather because when most nitroglycerin dynamite has been under water having a temperature lower than 50° F. it is likely to become more or less insensitive, which might prevent the charges from exploding the adjoining ones. The explosion may also fail to communicate from one charge to another through dry soil and when ditches are dug in this ground, each charge should be primed. The additional expense brought about by priming each charge can, however, be offset to some extent by placing the charges farther apart, and using a lower grade and cheaper dynamite—30 per cent. to 40 per cent. usually being satisfactory. In damp clay soil it is not often necessary to prime each charge but they should not be spaced farther apart than eighteen inches. Ditches from six to ten feet wide are blasted with two parallel rows of holes, the rows being from eighteen inches to three feet apart. With three parallel rows of holes ditches fifteen feet wide at the top and five feet deep can be dug with dynamite.

Blasting ditches has several advantages over other methods. Under many conditions it is cheaper, usually costing eight to ten cents per cubic yard of excavation, including explosives and labor and with the material excavated all disposed of. It is always much quicker than any other method, three men, under ordinary conditions being able to dig a thousand feet or more in a day. In swampy land covered with stumps, trees and underbrush it is the only feasible method, and is little if any more expensive there than in open country as the blast clears out all obstructions along the line of the ditch. It does not, like the hand or machine method of excavating, heap up the earth along the side of the ditch where it prevents drainage into the ditch and occupies ground that might be producing crops, but spreads it evenly over the adjoining land for some distance. Blasting also opens and fissures the ground on either side forming an almost perfect subsoil drainage into the ditch.

Blasted ditches are usually somewhat ragged looking at first but will square up almost immediately when the water enters them. They cave but little, if any, as the blast gives the sides a good slope.

When the location of ponds and swamps is such that the cost of draining them by ditching would be prohibitive, they can frequently be permanently dried up by blasting openings through the impervious subsoil underneath them which is responsible for their existence.

As this subsoil may be from five to thirty or more feet thick and the charge of dynamite should be located deep enough for it to break through into the stratum of sand, gravel or rock underneath, it is sometimes necessary to provide augers that will drill thirty feet deep. These augers are usually made by welding a two-inch dirt auger to a four-foot section of one inch or larger gas pipe. Other four-foot sections of the gas pipe, each with a collar or coupling, are also provided. The auger section is turned by means of a bar through a tee screwed on the upper end. As soon as this section is down as far as it will go, the tee is unscrewed, another section of pipe with the coupling permanently attached to the lower end is screwed on to the first section, and the tee is screwed to the second section. This process is repeated until the hole has reached the required depth. The explosive will usually give best results if located a foot or so above the bottom of the clay stratum, for if the charge is placed almost or quite in the more open stratum below it will expend its force in chambering that instead of shattering the clay above. It is necessary, of course, to use the first hole as a test hole and drill it down to the lower stratum. When the clay is underlaid by rock the charge of explosives should be put down on the rock. The explosion then breaks up the clay, opens fissures between the rock and the clay and may even crack and split the rock.

As this work is always wet, gelatin dynamite should be used. The 40 per cent. grade is about the proper strength. Holes six to ten feet deep usually require about five cartridges, holes ten to twenty feet deep ten cartridges and holes twenty to thirty feet deep, fifteen cartridges of the 1¼ x 8 inch size. It will usually answer the purpose if the holes are forty to fifty feet apart. Sometimes two or three properly blasted holes put down in the lowest part will drain a large pond. The blasting should always be done electrically as a fuse is likely to give trouble under water. No tamping is required, the water in the holes answering the purpose.

If the surface water is more than a foot or so deep, the holes can be drilled and charged from a raft. After the auger has been withdrawn the cartridges of explosives can be pushed to the bottom of the hole, one or two at a time, with a long straight stick. If given a good firm push when they are at the bottom, they will remain in the proper position. It is well when loading to use a section of one and a half inch pipe pushed down a few inches into the hole and extending a foot above the surface of the water. The cartridge primed with the electric fuse should be loaded last or next to the last. Then the section of pipe used in loading the hole should be lifted over the upper end of the electric fuse wires. These wires must next be connected to the two leading wires which should be carefully paid out while the raft is poled a hundred feet or more from the hole. The free ends of the leading wires may then be attached to the blasting machine, the operation of which will explode the charge.

The use of dynamite for other work about the farm, such as grading roads; digging cellars; excavating trenches for foundations, pipe lines, tiling, etc.; digging holes for poles and fence posts and sinking wells is too well understood to require more than casual mention. Nevertheless all of this work is necessary and cannot be economically accomplished without using dynamite and using it according to approved methods.

The Red Cross explosives are generally preferred for most of the blasting necessary about the farm because they do not freeze so readily as many of the other high explosives and are also somewhat safer to handle. They are too insensitive, however, to use satisfactorily for ditching when the whole line of charges is to be detonated by the one in the middle, and the fumes which they give off when detonated are more objectionable in close work like well sinking than the fumes from gelatin dynamite.

Carbon Tetrachloride as a Fire Extinguisher. J. A. ROBINSON. (*Eng. News,* lxv, 326.)—The electrolytic preparation of chlorine has made carbon tetrachloride an inexpensive article. Carbon bisulphide treated with chlorine yields carbon tetrachloride and sulphur dichloride; the latter is decomposed by injecting sodium hydrate and the carbon tetrachloride is purified by distillation. Carbon tetrachloride is a colorless liquid which boils at 78°C., but is non-inflammable and non-explosive, and its vapors stifle fire. The Interborough Rapid Transit Co., of New York, use it in fire extinguishers, and it is said to be preferable to water and sand for extinguishing arcs in electric installations. According to E. A. Barrier, the addition of tetrachloride to naphtha renders it fire-safe, but it must be applied in considerable proportions; a 70°C. naphtha or motor gasoline should contain 60 per cent. of the tetrachloride to be safe against explosion, and 70 per cent. to be fire-safe.

New Method for Electroplating Aluminum. (*Brass World,* vii, 202.)—Carl Rümpler, of Schöneburg, near Berlin, has patented a new method of electroplating aluminum. He claims that if a slight film of a brass deposit (containing as much zinc as possible) is first put on, the other deposits may be put on in the usual manner. He recommends a brass which contains not less than 50 per cent. of copper. A small quantity of a haloid, *e.g.,* potassium chloride, bromide or iodide is used in the plating bath. The brass solution recommended contains potassium and copper cyanide 5 oz., potassium and zinc cyanide 2 oz., sodium sulphite 5 oz., potassium hydroxide 2 oz., potassium chloride 1 oz., water 1 gal. Use brass anodes, and a current of 1.8 volts with a density of 2 to 3.6 ampères per square decimeter. The time for the formation of the brass film is from 1 to 2 minutes. Then proceed as usual.

Gyroscopes as a Means to Stability in Aeroplanes. GIRARD VILLE. (*Comptes rend.,* clii, 127.)—The gyroscopes used weighed about 5 k.g. and rotated at 6000 revolutions per minute. The gyrostatic action was used to cause rudders to work automatically. Experiments with a fixed apparatus were tried in a uniform air current, and also in the variable winds at the top of the Eiffel tower. It was found that the gyroscope with its pivoted frame tended to acquire an oscillatory movement, which was overcome by the use of damping planes immersed in water. This difficulty was not experienced when the apparatus was applied to gliders 12 metres square in area, the planes themselves being sufficient to damp the oscillations. The gyroscopic governor successfully compensated for disturbances of balance due to distribution of load and to variable winds and was used to advantage in a motor-driven aeroplane.

THE TEACHING OF ELEMENTARY CHEMISTRY.*

BY

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I. COMPLEXITY OF THE PROBLEM.

Chemical science is only about a century and a quarter old. As a special branch of knowledge, with its own objects and methods, it began with Lavoisier, who also wrote the first systematic text-book on the subject. The use of the laboratory as an aid in instruction dates only from the establishment of Liebig's laboratory at Giessen, in 1824. The High School laboratory is a recent phenomenon. It began only about thirty years ago and, even at present, laboratories are far from universal, while in many schools, the large size of the classes, the shortness of the laboratory period, the lack of all efficient laboratory assistance and the necessity of working up to a formal written examination throw grave difficulties in the way of the proper development of the work.

The High School treatment of chemistry is still in its formative stage, and this is especially true of the laboratory treatment, which is the more recent. The course in the classroom is prevented from taking any final definite shape by the rapid growth of the science. This growth perpetually produces new subject-matter which tends to displace the old. Electrochemical conceptions, which were hardly represented in the textbooks a decade ago, now dominate the whole treatment of large sections of the course. Colloid chemistry and radio-chemistry have hardly penetrated into the texts as yet, but they are handled in some way or other by all High School teachers of chemistry. The practical applications of the science demand an increasing amount of attention.

So far as the experimental work is concerned, the whole matter of High School laboratory instruction is so new that no sort of general agreement has been reached with regard to the most advantageous way of handling it. Whether the work should be all quantitative or all qualitative, or partly the one and partly the other are disputed questions. The fact that a qualitative exercise is hardly worth the time it takes, unless it is related in some very definite way to the general points of view of the science, seems to be scarcely appreciated as yet by the authors of text-books. The constant influx of new matter, both into the laboratory and class-room tends almost irresistibly to force the teacher into a kind of episodic treatment. He is obliged constantly to combat the tendency to allow his course to degenerate into a series of interesting but unrelated discussions of special topics, while the logical connecting structure which has produced all these developments, just as a tree produces its fruit, is slighted.

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*Presented at the meeting of the Section of Physics and Chemistry held Thursday, May 4, 1911.

The time devoted to chemical science in the High School averages about four hours a week for a school year of forty weeks. Half of this time is spent in the laboratory. It is plain that this scanty allowance bears no relation to the educational value of the science, nor to its practical importance to the student. The time might be doubled with advantage by extending the course through two years, but it is difficult to see where the additional hours are to come from and our present problem is to do the best we can with the time we have.

II. THE TEXT-BOOK.

One of the invariable features of the text-books of our science has been, for many years, the preference exhibited for the non-metals as the subject-matter of the early part of the work. This is most noticeable in Hoffmann's classical "Moderne Chemie,"[1] practically the whole of which is devoted to the non-metals and to the theory, the metals being scarcely referred to. In Friedrich Wöhler's excellent "Grundriss der unorganischen Chemie,"[2] the first fifty pages are devoted to general theoretical matters, and in the succeeding hundred pages the non-metals and their compounds are discussed. The balance of the book (two hundred pages) is devoted to the metals, which are dealt with in a compact, precise and altogether masterly way. The difference in the importance attached to the metals by these two great chemists is most interesting.

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[1] 6te auflage (1877).

[2] 15te auflage (1873).

The modern text-book authors have followed Wöhler rather than Hoffmann. That is, they take up the non-metals first and use them as the raw material from which to evolve most of the important general principles of the science while the metals are handled mainly in the second half of the book. There are, however, some important departures from Wöhler's order, most of which appear to be the result, first of a desire to acquaint the student with at least one metal in the early portion of the work and second, of an attempt to arrange the order of topics with reference to materials more or less familiar to the student. This second principle of arrangement is a most important one, since it is really the basis of all first-rate scientific exposition and the current type of text does not, in my opinion, allow sufficient weight to it.

III. THE ORDER OF TOPICS.

Anyone who will attentively examine the chief texts in the field will be surprised at the sameness of the order of topics. It may be said that, broadly speaking, water, air, salt and the periodic law furnish the skeleton of the conventional book.

The book begins with a general chapter, dealing with the scope of the science, with physical and chemical change, with mixture, compound, element, solution, combination, decomposition, and so on. It is plain that the student cannot possibly understand these generalizations until he has had at least one specific instance of each.

The authors meet this difficulty by intercalating illustrative experiments and these are nearly the same in all the books—salt water for solution, iron and sulphur for combination, mercuric oxide for decomposition, etc. An alternative method and, one might well think, a better one, would be to begin directly with the descriptive chemistry and to handle the abstract general matters as specific examples occur naturally in the course of the work. Why begin to generalize before the student is familiar with the facts which at once necessitate the generalization, render it intelligible, and supply the material for it?

The descriptive matter now begins with chapters devoted to oxygen, hydrogen and water. Practically all the books introduce the stochiometric laws, symbols, equations and the atomic and molecular theory at this stage. The use of water for the introduction of these generalizations began, I believe, with Hoffmann.

IV. AVOGADRO'S HYPOTHESIS.

Salt then serves to introduce chlorine and the atmosphere to introduce nitrogen and its compounds, after which the beginner, equipped with some knowledge of hydrochloric acid, ammonia, nitrous oxide, nitric oxide, etc., is considered ready to attack his *bête noire* Avogadro's hypothesis. In fact the course is arranged, up to this point, with the object of reaching Avogadro's hypothesis as rapidly as possible, so as to permit the use of molecular formulas (Compare Alexander Smith, "The Teaching of Chemistry," p. 54).

The universal trouble which beginners have with Avogadro's hypothesis is a curious phenomenon. In itself, the subject is not as difficult as some propositions in geometry, which the same students handle with ease. The difficulty is often due to the introduction of the subject before a sufficient foundation has been laid for it. Among the conceptions preliminary to Avogadro's hypothesis are those of gas, homogeneous substance, element, compound, mixture, atomic and molecular weight. These things are novel and difficult. They need to be treated in a practical and inductive rather than in a theoretical and dogmatic way. The last six ideas can hardly be imparted successfully without much laboratory work with *solids*, especially sulphur and the familiar metals.

When these seven conceptions have been deliberately worked out Avogadro's rule may be given, simply in *grams* and *litres* and enforced by illustrative problems. The molecular hypothetical presentation forms the natural conclusion of the subject. I have satisfied myself that the difficulties which beset the subject of Avogadro's hypothesis disappear if this course is followed. The only disadvantage is that the introduction of *molecular* formulæ is somewhat postponed, but this is not as serious as it looks at first sight. At present, we have decisive evidence for the molecular weights of gases and dissolved substances only. The innumerable formulæ of liquids and solids which we constantly employ are not truly molecular. HgO, FeS, NaCl, Na_2SO_4 and H_2O (liquid) are a few out of hundreds of instances with which our text-books bristle. We are practically without evidence with respect to the molecular weights of these substances and the formulæ are merely the simplest expression of the percentage composition. Of course this does not interfere in the least with their use in equation-writing or in solving problems.

For this reason, it seems to me that the importance of the early introduction of molecular formulæ has been greatly exaggerated. For instance, there is little consistency, in the present state of our knowledge, in forcing the student to write

$$2HgO \rightarrow 2Hg + O_2$$

instead of

$$HgO \rightarrow Hg + O.$$

The first equation is no more a correct representation of the mechanism of the change than the second. When the conception of molecular weight becomes applicable to solids we may be obliged to use a still more complex equation, *e.g.*,

$$Hg_{10}O_{10} \rightarrow 10Hg + 5O_2$$

but, at present, the simplest equation is the easiest for the beginner to handle and also the most scientific, since it keeps within the limits of our knowledge of the matter. Obviously the same remarks apply to similar cases like

$$KClO_3 \rightarrow KCl + 3O.$$

V. RESIDUAL TOPICS.

The next subject is Van't Hoff's extension of Avogadro's hypothesis to solution, which lead up to ionization and to the completion of the topic of acids, bases and salts.

At this point—roughly speaking, the middle of the book—a certain divergence of opinion becomes apparent. According to the manner in which the latter half of the work is arranged, the texts can be divided into three classes:

1. Those in which there is a chapter on the periodic law somewhere near the middle of the book, the periodic classification being followed after this point.

2. Those in which the periodic classification is followed through the latter half of the book, but the formal discussion of the law itself is postponed to the end.

3. Those which make no attempt to follow the periodic classification, but discuss the law itself at the end, in the light of all the knowledge which the student has gathered.

Excellent texts have been written according to all three of these plans, but the teacher who tries all three methods will conclude that the third offers the fewest disadvantages. The first is of course the most systematic, but it is almost unworkable with average classes. In a subject to which only about two hours a week in the class-room can be given, it is impossible, in half a year, to bring students to a stage at which they are ready to grasp the periodic generalization. If the teacher can reach this point with his classes at the end of the year he has done well and has every reason to be gratified with the result of his labors.

As for the second plan, the method of giving the facts first, and then erecting the generalization upon them, is usually by far the best approach to any abstract topic. But the periodic law is an exception. The material summed up in it is too extensive for the student to retain it until the time arrives for the setting up of the generalization. To classify tin with carbon, gold with sodium, manganese with chlorine and to lay stress on non-existent oxides, in the hope that, when the time comes to study the periodic law, the student will reap some advantage, is little better than a waste of time. It is far better to classify the elements in the simplest and most natural way, and to add whatever modifications are necessary, from the periodic view-point, in the chapter devoted to that subject. If the law is then given a candid treatment, which calls attention not only to its dramatic achievements, but also to its numerous puzzling defects, the subject will arouse the keenest interest of the students and will serve at the same time, as a valuable review of a large portion of the material of the course.

VI. SUMMARY.

It may be well to point out that we are making the assumption that the arrangement of the work is the same as that of the text employed, so that it is unnecessary to discuss the two separately. Thus far, we have devoted ourselves to what may be called, in no disparaging sense, the *conventional* type of book. At this stage it will be useful to sum up the results of our examination.

(*a*) The conventional text is constructed with the object of teaching the student the facts and results of chemical science, so far as possible during the very limited time available. The knowledge which it seeks to give is of the kind which can readily be tested by a written examination.

(*b*) As an essential feature of this programme, the stress is laid wholly upon the *subject-matter* while the *method* of the science is hardly noticed at all. Thus, a student who has mastered the treatment of the atmosphere in the current type of text will have a rather complete knowledge of the properties of the different gaseous constituents and the proportions in which they are present. With respect to the way in which all this knowledge has been acquired, or to the way in which he might go to work to investigate the matter for himself, he will have only the haziest ideas. If his knowledge is called into question, he will probably be unable to defend it, except by reference to the books where the statements are to be found. The conventional text is almost wholly dogmatic—as distinguished from inductive—in its presentation. Everything is communicated—hardly anything is proved. Little space is given to the historical side of the science, for teaching chemistry along historical lines is almost the same thing as teaching it inductively. In both plans, the effort is to show how the generalizations arise out of the facts and both will, in at least nine cases out of ten, lead to the same order of presentation of a topic.

(*c*) Another aspect of dogmatic presentation is that the orderly development of the student's ideas, which is really the whole object of the work, is relegated to the background as a minor matter, the main aim being to achieve a compact, accurate, systematic statement of the facts and principles the student is to learn. In this the shadow cast by the impending examination is plain.

The desire for compactness is probably responsible for the way in which substances and processes totally strange to the student are employed at the beginning of the work. In the introductory chapter of his text the student usually finds himself confronted with sulphuric, nitric, and hydrochloric acids with mercuric oxide, potassium chlorate, silver nitrate, sodium and carbon disulphide, with solution, crystallization and electrolysis.

I venture to think that there has been too much of this sort of thing. It is, of course, an important part of our business to enlarge the student's knowledge of the elements and their compounds, but the enlarging should be done in a logical way. The introduction of an unfamiliar substance, before the time has come for its full discussion, is a serious evil, and it is an evil which can usually be avoided by a little care in the arrangement of the work.

VII. THE HEURISTIC METHOD.

We may permit ourselves, then, to indulge in the paradox that the current type of chemical text is essentially a *popularized* form of chemical science. It is popular in the sense that its leading aim is to achieve a general survey of the results of the science, without much reference to the process by which those results are obtained. Strictly scientific literature contains not only certain results of investigation, but also the rigorous evidence which will convince all normal men, who will take the trouble to analyze it, that those results are correct.

The *heuristic* method which, under the energetic advocacy of Prof. Armstrong, has had a profound effect upon the teaching of our science in England—abandons, at the start, all idea of making a systematic survey of the subject. The stress is laid, not upon the results, but upon the method of the science, and the student is put in the attitude of an investigator from the first. The early part of the work is confined to familiar materials, such as sulphur and the common metals, water, air, salt and pyrite. The facts obtained by simple experiments are gradually organized, without any effort to hurry the development of the generalizations.

There is no doubt that the advocates of the heuristic method have grasped an educational factor of great importance. The objection often made that it is useless to train students in research because so few of them will become investigators is no answer to their contention. Research is simply the solving of problems by observation and experiment and every man whose function requires something more than mere routine work is of necessity continually engaged in investigation. The problem, for instance, of reducing the cost of a manufacturing process is fundamentally scientific and is to be solved by methods very similar to those which enable a student to ascertain whether copper and sulphur do or do not unite in fixed proportions by weight. And there can be no question that the ability to attack a problem aggressively by experiment and to think accurately in interpreting the results is far more valuable, as a preparation for life, than even the most encyclopedic knowledge of facts.

Much damage has been done the heuristic method by the extravagant claims of some of its friends. Consider, for instance, this passage from Arendt[3]: "Die Schüler haben die den chemischen Erscheinungen zugrunde liegenden Ursachen selbst auszufinden und die zum Ziele führenden Versuche und die Art ihrer Ausführung anszudenken. Der Versuch werde stets zur Erforshung einer Ursache veranstaltet; die Theorie werde aus der Beobachtung entwickelt, und zwar müssen die Schüler die allgemeinen Begriffe und Regeln selbst ableiten."

The services which Prof. Arendt has rendered to chemical education are great, but this particular passage is little better than pure nonsense. A course in which the student was required to recreate the science—experiments, theory and general principles—for himself would be wholly unworkable, for it assumes the possession of superhuman intelligence. The great investigators have won their imperishable renown by doing, for small portions of the science, exactly what Arendt would require each student to do for the whole subject. Supposing that the start was made in the simplest possible manner by heating sulphur with familiar metals, it is doubtful whether the student would come unassisted to the conclusion that the substances supplied to him were elements and that he was dealing with cases of combination.

VIII. COMPROMISE.

It will not answer simply to assume that the student must find out everything for himself, for this would forbid all progress. How much he is to find out and how much is to be communicated to him must be decided by careful consideration of each topic. For instance, the proof that copper and sulphur are elements is clearly beyond the powers, not only of the beginner, but also of the advanced student. But *assuming* that copper and sulphur are elements, the proof that, when heated together, they combine in definite proportions by weight forms an exercise which the beginner will work out with surprising enthusiasm and exactness.

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[3] Compare *Zeitschr. für Phys. u. Chem. Unterricht*, vol. xxii, p. 102.

The intelligent, practical limitation of the heuristic method forms a complex problem which has been most successfully solved, so far as I know, by Otto Ohmann of the Dorotheenstädtischen Realgymnasium at Berlin.

In handling the atmosphere, for instance, the usual course is to describe oxygen, to describe nitrogen, to tell the student that these two gases in certain proportions make up the chief part of the air, which, however, contains smaller quantities of other substances, and so on.

Before attacking the atmosphere, Ohmann's book[4] gives the student an opportunity—from work with sulphur, the familiar metals and some mineral sulphides—to form the conception of element, compound and mixture. The chemical study of the air is then begun by investigating the effect of heating metals in it, at first qualitatively and then with reference to increase in weight. By heating a folded piece of sheet copper and noting the absence of action in the interior it is proved that air as well as heat is concerned. The familiar experiment in which iron-powder hanging to a magnet is heated in a bell-jar over water is next applied to prove that only a portion of the air disappears and this is followed by the passing of a measured volume of air through a tube containing heated copper, the residual gas being collected over water. Thus *nitrogen* is reached before oxygen. After the properties of nitrogen have been briefly studied, oxygen is obtained by heating mercuric oxide. This is introduced not by name, but as a red powder which bears the same relation to mercury as the black powder obtained by heating copper in the air does to copper. The student's knowledge of oxygen is then enlarged, with the aid of a cylinder of the compressed gas.

Other topics are handled similarly. It is plain that a student who studies chemistry in this manner will not only know something about it, but will also know *how* he knows it. He will have some idea of the way in which the science goes to work to get its subject-matter, which is at least as important to the student as that subject-matter itself. It is also clear that a subject handled in this way is taken up essentially in the historical order. This is more than a mere coincidence. As Goethe remarks, in his brief but exhaustive way, "Die Geschichte der Wissenschaft is die Wissenschaft selbst."

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[4] "Leitfaden der Chemie," 5te aufl. (1910).

THE HANDLING, TRANSPORTATION, AND STORAGE OF PERISHABLE FOODSTUFFS.*

A REVIEW OF THE WORK OF THE FOOD RESEARCH LABORATORY, BUREAU OF CHEMISTRY, U. S. DEPARTMENT OF AGRICULTURE.

(*Contribution from the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.*)

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.

PART II.

THE SCIENTIFIC STUDY OF THE HANDLING OF PERISHABLE FOODSTUFFS.

COMMERCIAL METHODS 173—SCIENTIFIC INVESTIGATION OF COMMERCIAL METHODS IN THE FIELD 183—HARD FROZEN POULTRY 186—CHEMICAL CHANGES AND BACTERIAL GROWTH IN MILK AT LOW TEMPERATURES 186—STUDIES OF EGGS 189—CONCLUSION 191—BIBLIOGRAPHY 192.

COMMERCIAL METHODS.

THE study of poultry handling has formed a large part of the work of this laboratory. The various commercial methods of dressing, transporting, storing, and marketing have been studied in the field and have been investigated in the laboratory, in order to learn which methods will produce a bird of the best quality for the consumer.

The eastern portion of the United States does not raise sufficient poultry to supply the demand of its own markets. By far the greater portion of the market poultry of the country is a product of the corn belt. The methods of breeding and feeding chickens have been studied in detail in the Eastern States, with a consequent increase in the quality of the eastern bird; in the corn belt, with its large farms, it has not been possible to study these particular branches of poultry husbandry, therefore in order to obtain a market product which will compete successfully in the eastern markets with fowls from nearby farms in respect to quality, the western packers have been obliged to place great stress upon the killing, picking, chilling, packing, and transporting of chickens.

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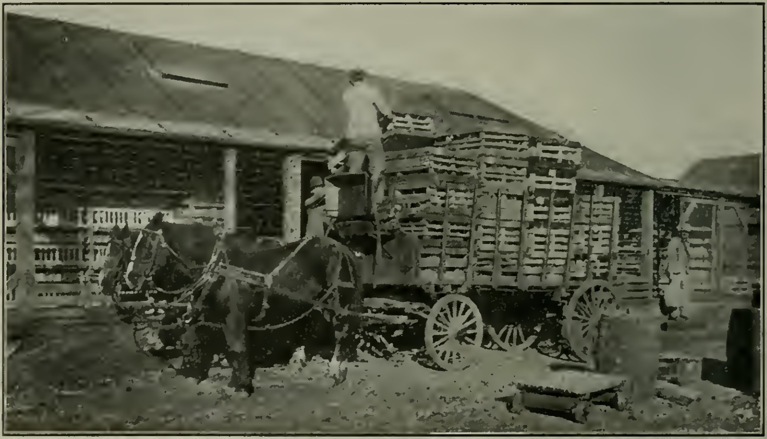
* Presented at the Stated Meeting of the Institute held Wednesday, May 17, 1911.

In the poultry belt chickens are prepared for market at packing houses. The birds may be taken directly from the farm to the slaughter house, or they may be submitted to a fattening process in a feeding station, then be removed to the packing house for slaughter. The killing of chickens is carried out in several ways. In bench killing the beak of the bird is fastened at the lower end of an inclined bench; in string killing the fowl is suspended by its legs by means of a rope; in either case the bird is killed by means of a knife-cut in the mouth. Other methods of killing exist, thus the bird may be held under the arm while administering the fatal cut, or the neck may be broken by mere muscular force. Since bad bleeding of a chicken leads to more rapid deterioration than occurs in a well-bled bird, an anatomical study has been made of the blood-vessels of the head and neck of the chicken, in order to devise a method of cutting which will insure proper bleeding. Two large veins run the whole length of the neck, one on each side, and are united by a diagonal "bridge vein" which is just below and behind the ear, and is farther front on the left side. This bridge vein lies just beneath the skin of the roof of the mouth and passes directly

FIG. 1.

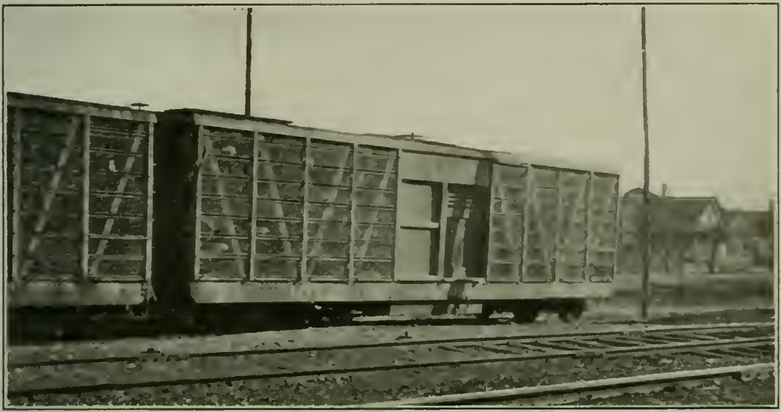


Arrival at the packing house of chickens from the farm.

across the U-shaped depression in the skull into which the upper part of the spinal column fits. By cutting the left neck vein and the bridge vein at their junction in the mouth of the chicken, good bleeding is insured. Moreover, the bones of the skull offer a backing to the knife and prevent it from sinking too deep, thus collection of blood in the soft tissues of the neck is prevented. It is interesting to note that at least thirty per cent. of the poultry coming to the New York market is incompletely bled.

The process employed for picking poultry varies. The birds may be scalded in order to loosen the feathers, then picked; since scalding is highly destructive to the structure of the skin, which serves as a protective coat to the carcass, a scalded chicken deteriorates rapidly. If the bird be dry picked, it is not only cut so as to bleed well, but the brain is pierced as well. The knife is run under the eye at such an angle that its point will touch the skull midway between the eyes and a little behind them; or the knife is placed half way down the groove in the roof of the chicken's mouth then thrust upward until it reaches the top of the skull midway between the eyes. The point of the knife is moved backward and forward slightly to destroy enough brain tissue to paralyze the bird, yet not kill it instantly. The resulting paralysis of the feather muscles facilitates dry picking. The rough picking may be done on the killing bench.

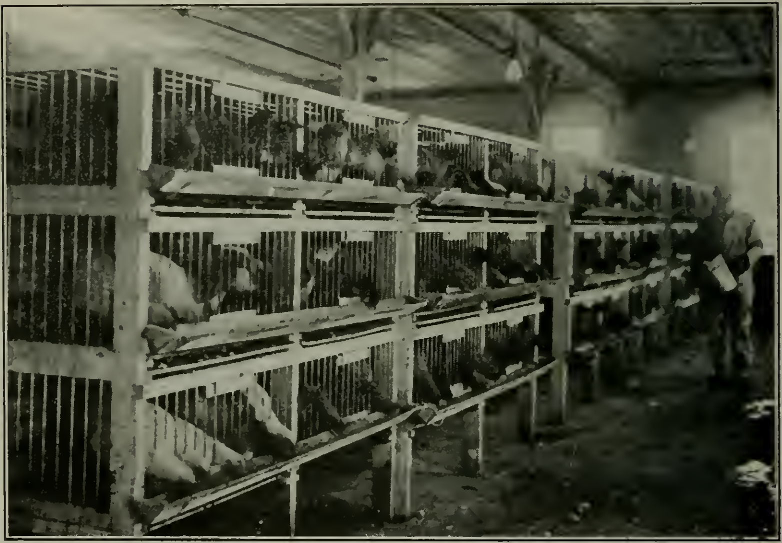
FIG. 2.



Railroad cars for transportation of live chickens.

or may be carried out while the bird is suspended by its legs by means of a rope. For the final picking or "pinning" suspension by a rope may be utilized as in killing and rough dressing, or the workmen may hold the birds on their laps during the process. "String" killing, roughing and pinning form the better procedure. During picking, care should be taken to avoid rubbing or tearing the skin, and thus opening the way for bacterial invasion and loss in quality.

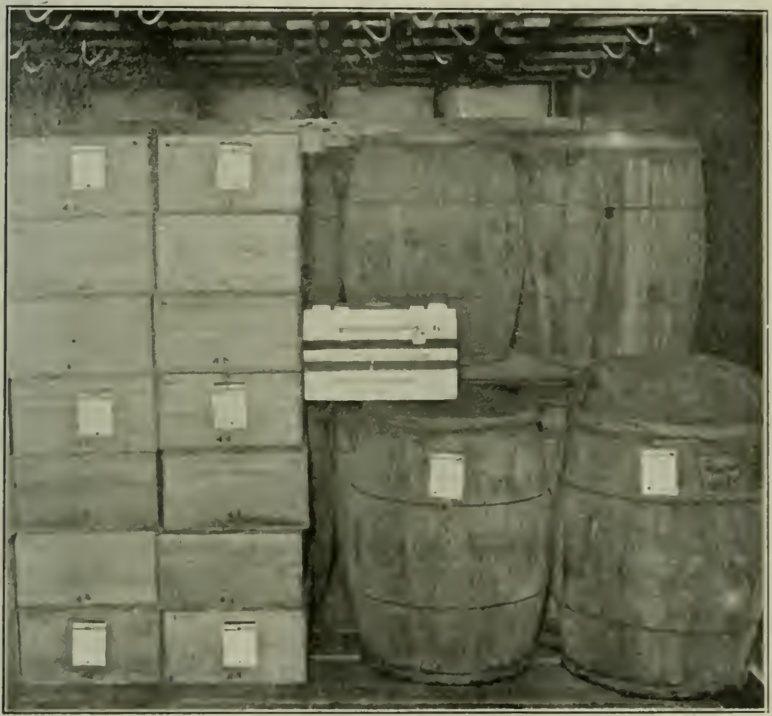
FIG. 3.



Interior of a feeding station—feeding pens.

The dressed poultry may be cooled in water and packed in cracked ice; or it may be cooled in air in an artificially refrigerated chill room, then packed dry. In the latter procedure, the birds are placed on movable racks and are subjected to a temperature of 35° to 40° F. (2° to 4° C.) in a chill room, which is provided with mechanical refrigeration, until the greater part of the animal heat has been removed, then they are transferred for the final chilling to a second chill room, the temperature of which is kept below 35° F. (2° C.), preferably at 30° F. (—1° C.). The packing should be done in the second chill room. The chickens are usually packed in small boxes, each of which holds one dozen birds. Broiling chickens are packed with the breast up and the feet hidden, one dozen broilers form a layer and but one layer is placed in a box. Roasting chickens or fowls are laid on their side, six birds form a layer and two layers are placed in a box. The general tendency is to eliminate pressure on the tender tissues of the chicken as far as possible, therefore heads are wrapped in parchment paper and turned back so that they rest against the bony structure, rather than against the soft flesh of the thighs and breast; and the package is made smaller and smaller. Fowls are now sometimes packed a single layer to the box, and the carton for the single chicken or at most a pair of chickens is a recent advance which is

Fig. 4.



Experimental shipment in a refrigerator car. In the background are the ice bunkers. The boxes on the left contain eggs. Two barrels are in the foreground; the one on the right, in which the contents cause the cover to protrude above the top of the barrel, contains ice-packed chickens; while the one in the centre, with the cover level with the top of the barrel, contains dry-packed chickens. The locked box, which rests on the latter barrel, contains a thermograph.

gaining in favor. If the boxes are held for several days before shipment from the packing house, they are kept in the chill room of lowest temperature or are placed in a "freezer" at a temperature of 0° to 15° F. (—18° to —9°C.), for from twenty-four to forty-eight hours. When not more than twelve chickens of ordinary size have been packed in a box, a period of forty-eight hours in a good freezer will very thoroughly harden the birds; a number of such boxes in a refrigerator car is a valuable aid in maintaining an equably cold temperature.

The boxes are always transported in refrigerator cars, so that the chickens may be kept at such a temperature for such a period of time, that they will reach the point of consumption in good condition after a railroad haul of one thousand miles or more. The bunkers of refrigerator cars, which are used for the transportation of dry packed poultry, are chilled by means of fine ice mixed with from 10 to 15 per cent. of salt. This mixture will maintain the temperature of the middle of the car, four feet from the floor, at 40° F. (4° C.) or under, provided the car be built with sufficient insulation and be in good order, *i.e.,* have tight-fitting doors, unbroken lining, etc. The boxes containing the most recently killed chickens are placed next the bunkers where the temperature frequently falls to 10° F. (—12° C.), and where the air about the top layer, 4 feet from the floor, often has a temperature not exceeding 30° F. (—1° C.). The boxes which have been in the freezer are packed together as tightly as possible in the central part of the car, and thus serve as a source of cold, where cold is most needed, *i.e.,* in the middle of the car, where refrigeration from the bunkers is least. The height of the load should not exceed four feet from the floor of the car. The cars are inspected and iced at icing stations during the railroad haul.

After poultry has been chilled or frozen the low temperature should be maintained constantly until the product is consumed, for a fluctuation in temperature is accompanied by a condensation of moisture, which creates a favorable environment for the action of bacteria and enzymes, and thus gives rise to decomposition. The wholesale dealer should keep dry packed poultry, between receipt and disbursement, in a mechanically refrigerated chill room at a temperature below 40° F. (4° C.). Frozen poultry should be carried in a room which is kept at a temperature below 15° F. (—9° C.). The retail dealer usually keeps his stock of chickens in an ice-box, the temperature of which is about 45° F. (7° C.). However, even the retailers are beginning to use mechanical refrigeration, by means of which they may keep their poultry at a chill room temperature.

Water cooled chickens are always packed in barrels between layers of ice, and are kept in contact with ice until they reach the retail dealer. The barrels are usually transported in refrigerator cars. The retail dealer generally places his wet- (or ice-) packed chickens in a drained, zinc-lined box and mixes them with fine ice.

Air-chilling and dry packing would seem to offer a better mode of marketing than water-cooling and ice-packing. The latter process is uncleanly, places much pressure on the tender tissue of chicken muscle, and injures the skin, thus opening the way for bacterial invasion. Scientific research has proved the truth of these contentions. A bacteriological study has been made of the skins of chickens chilled in dry air, and in water and ice. After even a short keeping time, as market practices go, a markel preponderance of organisms was found in the skins of the birds which had been cooled in water and ice. The following data show that the acidity of the crude fat of chickens, which is a measure of decomposition, increases more rapidly in water-chilled, ice-packed chickens, than in air-chilled birds kept at 32° F., in dry air.

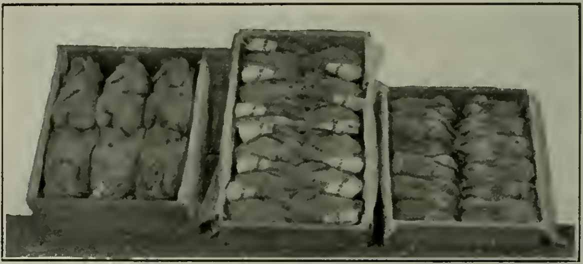
ACIDITY OF FAT AS AN INDEX OF FRESHNESS.

History of sample.	Acid value.
Broilers, air-chilled, 48 hours old	0.95
Same lot after 4 days, at 32° F	2.10
Same lot after 12 days, at 32° F	4.74
Fowl, air-chilled, 8 days at 32° F	1.65
Same lot, 12 days, at 32° F	2.41
Fowl, kept at 32° F. for 3 days	.80
Same lot, kept at 32° F. for 6 days	1.41
Broilers, water-chilled, ice-packed, 48 hours old	0.88
Same lot, 4 days in ice	4.57
Same lot, 7 days in ice	4.71
Fowl, water-chilled, ice-packed, 8 days	8.55
Same lot, 10 days in cracked ice	8.86
Fowl, kept in ice 3 days	2.20
Same lot, kept in ice 6 days	2.70

An extensive chemical and bacteriological study is now being made of the marketing of air-cooled, dry-packed chickens and of water-cooled, ice-packed birds.

Dry packed poultry may be either drawn or undrawn. If drawn, the drawing or evisceration may be "full drawn," "wire drawn" or "Boston drawn." In "full drawing" the body cavity is opened by a transverse cut across the abdomen and the vent is removed by cutting around it. The head is cut off and the intestines and viscera are completely removed. The heart, liver, cleaned gizzard and excess body fat are placed in the body cavity. The shanks and feet are removed and the hocks are thrust through the opening in the abdomen and the vent.

FIG. 5.



Dressed chickens packed in boxes, one layer to the box. On the left, roasters, six birds to a layer, packed on their sides. In the centre, broilers, twelve birds to a layer, "squatted" *i.e.*, packed with their backs up, and their heads and necks laid across the opposite birds. On the right, broilers, twelve birds to a layer, packed with their breasts up and their necks, heads and feet hidden.

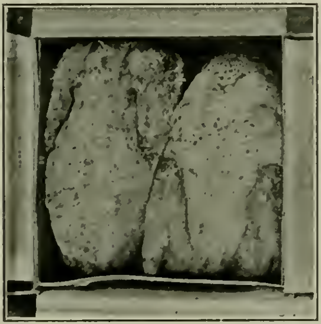
"'Wire' drawing consists in pulling out a loop of intestine by inserting the finger through the vent; cutting the loop, and drawing out the gut by careful traction until it breaks at the gizzard. The vent of a bird so drawn presents a normal appearance; the only indication of drawing is the collapsed abdomen.

"The 'Boston' drawing is a modification of the 'wire' in that a circular incision is made around the vent and the intestines pulled through until rupture occurs at the gizzard." The undrawn fowls are shipped with heads and feet on, and no incisions are made except for bleeding and braining.

Full drawn poultry decomposes the most rapidly during the interval between dressing in the packing house and final sale by the retailer in the city; Boston drawn and wire drawn birds decompose less rapidly than the full drawn chickens, but more rapidly than the undrawn; the wire drawn birds usually suffer less decomposition than the Boston drawn. Undrawn poultry decomposes more slowly than that which has been entirely or partially eviscerated. These deductions are based on a study of the bacterial content of the wall of the abdominal cavity and on determinations of the acidity of the crude abdominal fat and of the quantity of loosely-bound or ammoniacal nitrogen present in the flesh.

Poultry may be held for weeks in a chill room or may be frozen solid and kept in that condition; in the former case it is sold as "fresh," while in the latter case even if held for only a few weeks it is termed "storage." If a chicken be scalded or water-cooled, it will deteriorate rapidly even when hard frozen. If a bird be in the incipient stages of decomposition when hard frozen, deterioration will progress while in that state and decomposition will be rapid after thawing. Only dry picked, dry chilled poultry should be put into cold storage. Since the freezing should be rapid, the containers should be comparatively small, barrels should be avoided and boxes should be used. In order to exclude air from the birds, recourse is had to tight packages. Each chicken is wrapped in parchment paper when the stock is high grade; the result is two fold, the birds cannot rub against each other, and they cannot freeze into a solid mass. The packer usually ships poultry, which is to be stored, in a

Fig. 6.



Pasteboard carton for two chickens with the lid removed. The wide border is formed of portions of four similar cartons with closed lids.

refrigerator car to a cold storage warehouse; all possible precautions against bad treatment are taken. At the warehouse the boxes of poultry are kept in a room with mechanical refrigeration, at —10° F. (—23° C.) for several days, until the chickens are completely frozen. The boxes are then transferred to another room with a temperature of 10° F. (—12° C.) where they are kept until placed on the market.

Only poultry of good quality should be stored. If the chicken be poorly dressed, *e.g.*, scalded or water-cooled, or if it be in the early stages of decomposition, its quality will not be improved by its storage in the frozen state. In fact even the best of poultry is not improved by being kept frozen for any length of time. About the sixth month of carrying the sense of taste of a careful observer reveals a difference between frozen poultry and that freshly killed. However, up to nine months, the difference is so slight that it is of scarcely more than scientific interest. After nine months the flesh is undoubtedly wholesome and nutritious but a loss in flavor has occurred, proportionate to the period of storage.

It is highly desirable that frozen poultry be sold at retail in the frozen state, and that thawing occur in the ice box of the consumer. If the chicken be frozen by the packer, it should be allowed to "ripen" for several days in the ice box, or it will have a flat flavor. If the poultry has been several days in transit to the storage warehouse, and has been merely chilled prior to its arrival at that place, as soon as the bird has thawed in the ice box, it will be found to possess a good eating quality. Birds should not be thawed commercially by placing them in cold water, for such a procedure not only gives rise to rapid decomposition, but also removes a considerable portion of the flavor. Since the flavor is the first attribute of the fresh chicken to disappear during storage in the frozen state, care should be taken to retain the flavor in frozen birds, therefore thawing in water should be avoided. Thawing is best carried out by hanging the chickens in cool air, which is kept at the temperature of an ordinary ice refrigerator, the air should be circulated, to evaporate any moisture, which may settle upon any of the birds. Twenty-four hours should suffice for thawing a chicken of ordinary size, though a large roasting chicken may require a slightly longer period of time.

"So thawed, a bird well prepared and stored for a reasonable length of time—that is, from one season of production until the next as a maximum—will have a clear, fresh color in the skin, which will be soft in texture, slipping easily from the muscles beneath it. The flesh of breast and thighs may be very slightly deeper in color than in the fresh specimen, but so little that the change is negligible from a practical view-point. The fat is generally a little deeper in color and may have a slight taste and odor of rancidity."

After frozen poultry has been thawed and placed on the market, it should never be returned to the freezer. Refreezing is never a success, for loss in quality occurs after a second thawing. While the refreezing of poultry thawed in air is decidedly deleterious, that which is thawed in water and refrozen is in a much worse condition.

SCIENTIFIC STUDY OF COMMERCIAL METHODS IN THE FIELD.

In a scientific study of poultry handling, it is necessary to trace the history of a chicken from the time it arrives at the packing house until it finally reaches the consumer. The mode of killing, dressing and chilling must be known, a record must be kept of the transportation, and the bird must be followed through its stay—be it long or short—at the warehouse until it passes into the hands of the retail dealer, and then of the consumer.

A branch- or field-laboratory is installed in the packing house, so that a quantitative analysis, both chemical and bacteriological, may be made of the sample after the chilling process has ended and the birds are about to be packed. Visual "inspections" of such properties as odor, color of skin, etc., are made during the marketing as are also chemical and bacteriological analyses. It is impossible to express visual inspections in quantitative terms, and moreover such observations are influenced to a great extent by the personal equation of the observer. Chemical and bacteriological analyses are very delicate and accurate, are quantitative and are much less dependent upon personal equation.

A brief description of the research, upon the comparative rate of decomposition of undrawn poultry and that which had been drawn in various ways, will give an idea of the nature of the field work of this laboratory. Large mature hens were killed by cutting the blood-vessels of the neck from within the mouth, and the brain was also punctured. They were well-bled, dry-picked, air-chilled; some were undrawn, others were eviscerated entirely or partially by the various methods of drawing (wire, Boston, full) which have been described in the preceding chapter. From their entrance to the chill room until their withdrawal from the retailer's for final analysis, the chickens were accompanied by a thermograph in order to obtain a complete record of the temperature. The birds were exposed for from twenty-four to forty-eight hours in a chill room which had a temperature between 27° and 41° F., with an average of 34° F. A sample was then analyzed; the other fowls were wrapped, boxed and placed in a refrigerator car, if a car lot was ready for shipment; otherwise they were held in a freezer at about 12° F. for three days on an average until a car was loaded.

The experimental packages formed part of an actual commercial shipment from the packing house. They were placed in the centre of the car, not more than four feet above the floor; the bunkers were filled with salt and ice, and instructions for icing en route accompanied the car. A period of seven and one-half days was usually required for the railroad haul of about 1700 miles. When the car arrived at its destination, the boxes were transferred to the chill room of the wholesale dealer, which had an average temperature of 32.6° F. The chickens were inspected and a sample taken for analysis. From the wholesaler the boxes were removed by wagon—a short haul—to the retail dealer. Since the equipment and methods of retailers vary within wide limits, arrangements were made for several of these dealers to participate in the research. They used the ice box for refrigeration. Whenever a display was made, the birds were hung in the shop window. The average temperature, including that of the window display, was 48° F. Inspections were made and samples removed for analysis when the retailer had sold at least one-half of his stock from the car lot of which the experimental packages had formed a part, and again "at the very last of the marketing or a little later than the retailer's regular sales, if the general market happened to be dragging." These samples, two from the retailer and one from the wholesaler, were submitted in this laboratory to chemical and bacteriological analysis, including the determination of the acidity of the crude abdominal fat (as a measure of fat decomposition), the quantity of loosely-bound or ammoniacal nitrogen in the flesh (as a measure of protein decomposition), and the number of bacteria per gramme in the abdominal wall.

In these experiments all disturbing factors such as bad bleeding, had been eliminated. The birds differed only in mode of drawing; they had been subjected simultaneously to the same definite conditions of killing, picking, chilling, transportation and final marketing, therefore any differences between the chickens entirely or partially eviscerated and the undrawn birds, must be ascribed entirely to the method of drawing. A series of eleven shipments were included in this research which extended over a period of six months from January to June. From the average results of the analyses of the samples comprising these eleven experimental shipments, the following conclusions follow. Throughout the entire marketing period, the acidity of the crude abdominal fat increased progressively in all the samples, undrawn, wire, Boston and full drawn. The increase in acidity was greatest in the full drawn birds, in fact even in the packing house they had a slightly higher acid value than the other samples.

During the marketing, especially during the sojourn at the retail dealer's, the ammoniacal nitrogen in the flesh underwent a progressive increase, which was greatest in the full drawn chickens.

The number of bacteria in the abdominal wall also increased progressively. During the entire period, the undrawn birds contained the fewest and the full drawn the greatest number of organisms per gramme.

At the warehouse of the wholesale dealer or commission man, differences in quality due to mode of drawing were scarcely revealed by visual inspection. However, during the period of retail marketing, these differences became visible to a marked degree. Though stale, the last samples of undrawn chickens were still edible with a single exception; the wire drawn fowls were close to the undrawn; the Boston drawn birds were of a distinctly lower grade and occasionally were no longer edible. The full drawn chickens were always in the worst condition and frequently were no longer fit for food.

As already stated, the delicate and accurate methods of quantitative chemical and bacteriological analysis detect differences in quality due to mode of dressing even at the wholesaler's. These quantitative methods demonstrate that deterioration is progressive and is most rapid in the full drawn fowls and least rapid in the undrawn. The wire drawn and Boston drawn birds lie midway between the undrawn and full drawn; the wire drawn, which are more like the undrawn, are usually the better.

HARD FROZEN POULTRY.

The changes which occur in hard frozen poultry have already been mentioned in *Part I*. The flesh undergoes a desiccation with consequent increase in total solids and decrease in water content. The protein suffers a slow and specialized proteolysis, similar to that produced by the enzyme trypsin. The fat increases in acidity, and the saponification number and Hehner number change in the same direction simultaneously. The changes in the flesh, which are revealed by histological study, suggest an autodigestion. The bacteria which proliferate at 20° C., tend to increase. These changes, however, are chiefly of scientific interest. If a bird be given the proper treatment before, during and after storage in the frozen condition (as described in the chapter on Commercial Methods), it may be stored for a reasonable length of time, with the period from one season of production to the next as a maximum, without loss in food value.

CHEMICAL CHANGE AND BACTERIOLOGICAL GROWTH IN MILK AT LOW TEMPERATURES.

Milk has been kept at or a little below a temperature of 0° C. for periods ranging from a few days to almost two years. Under these conditions the casein undergoes a rapid digestion until finally more than fifty per cent. of it has changed to soluble compounds, and an increase in caseoses, amino acids and probably peptones occurs apparently at the cost of the digested casein. The proteolysis is pronounced at the end of two weeks, although it may vary in rapidity in different samples. The acidity of the milk increases at low temperatures and after several weeks is much higher than is required to produce a

TABLE I.

CHEMICAL CHANGES IN RAW MILK KEPT AT 0° C.

The Figures in Roman Represent the Per Cent. of the Various Forms of Nitrogen and the Per Cent. of Lactose in the Milk. The Figures in Italic Represent the Various Forms of Nitrogen as Per Cents. of the Total Nitrogen.

Period of keeping in days.	Distribution of the nitrogen.							Lactose.	Acidity c.c. $\frac{N}{10}$ NaOH per 100 c.c. of milk.
	Total nitrogen.	Casein nitrogen.	Albumin and syntonin nitrogen.	Caseose nitrogen.	Amino acid and ammonia nitrogen.	Difference between total nitrogen and sum of constituents determined.	Free ammonia nitrogen.		
Fresh	0.585	0.457 *78.12*	0.069 *11.79*	0.033 *5.64*	0.007 *1.20*	0.019 *3.25*	0.00047 *0.080*	5.3	18.0
7	0.571	0.432 *75.66*	0.084 *14.71*	0.018 *3.15*	0.018 *3.15*	0.019 *3.33*	0.00046 *0.080*	5.2	16.5
14	0.566	0.377 *66.61*	0.081 *14.31*	0.000 *0.00*	0.032 *5.65*	0.076 *13.43*	0.00000 *0.000*	3.8	32.7
21	0.569	0.335 *58.88*	0.069 *12.13*	0.167 *29.35*	0.033 *5.80*	*0.035 *6.15*	0.00075 *0.131*	3.7	30.7
28	0.537	0.295 *54.93*	0.053 *9.87*	0.161 *29.98*	0.022 *4.10*	0.006 *1.12*	0.00113 *0.210*	3.3	46.5
35	0.572	0.286 *50.00*	0.066 *11.54*	0.136 *23.78*	0.044 *7.69*	0.040 *6.99*	0.00040 *0.069*	3.5	56.0

* The sum of the nitrogenous constituents determined is greater than the per cent. of total nitrogen in this sample by 0.035 per cent.

curd spontaneously at ordinary temperatures; yet the phenomenon of curdling rarely occurred, in fact milk with an acidity as high as 101 c.c. of $\frac{N}{10}$ sodium hydroxide to 100 c.c. of milk did not form a curd even after exposure to the temperature of an ice box for days. A decrease in the lactose content also occurred. Table I shows the chemical changes undergone by a raw milk kept at 0° C. for 5 weeks, and analyzed when fresh and at intervals of one week thereafter.

Bacterial growth in milk stored at low temperatures was pronounced at the end of a week, even in the cleanest milk. The organisms always increased in number for five or six weeks and reached a maximum of hundreds of millions and occasionally of over a billion to the cubic centimetre. This enormous increase in bacterial content occurred in spite of the fact that the milk had been converted into a semi-solid mass of ice crystals by prolonged exposure to a temperature of 29° to 31° F. However neither odor nor taste indicated the presence of the enormous number of organisms, and the milk did not curd even on heating; in fact to the ordinary observer it was still suitable for household use, until the bacterial content began to decrease and the organisms of putrefaction made their presence known. Neutral organisms were present as well as those which form acid and those which act on protein. The liquifying organisms were more numerous and the acid forming bacteria were present in relatively smaller numbers than in milk kept at higher temperatures. "Certain species such as *B. formosus*, *B. solitarius*, and *B. Ravenel*, were especially resistant to cold and frequently were the predominating species, or almost in pure culture at the close of the experiment."

"A very marked difference in both the number and kind of organisms which developed on the plates was noticed, depending upon the temperature at which the plate was incubated. In certain experiments the maximum number grew at 37° C. In others the temperature at which the milk was stored served best for colony formation. The relative number of organisms growing at 37° C., 20° C., and 0° C., or a little below, varied greatly also with the length of time that the milk had been kept in storage, the organisms developing at body temperature being ordinarily greatly in excess at the beginning of the experiment and diminishing until near its close, when a sharp rise was apt to take place."

When very fresh milk was kept in the laboratory at a temperature of 18° to 22° C., bacterial growth was rapid and profuse; the acid forming organisms were in high proportion and the liquifying organisms were relatively lower. The milk ordinarily curdled when the acidity had risen to between 23 c.c. and 28 c.c. of $\frac{N}{10}$ sodium hydroxide per 100 c.c. of milk. At this point only about one per cent. of the casein had been digested with the formation of soluble products.

STUDIES OF EGGS.

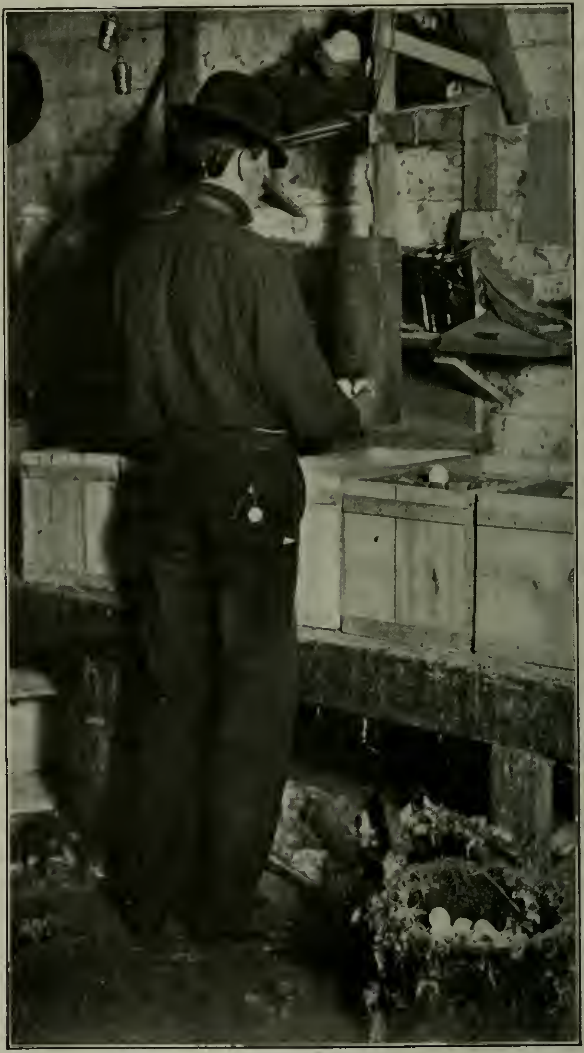
In the chemical study of eggs it became necessary to devise certain analytical methods. Thus the separation of white and yolk of raw eggs offered difficulties which were overcome in the following manner: the shell was broken, the white was poured off as completely as possible, and the yolk was washed free from white while still in the shell, by means of a gentle stream of water directed from a wash bottle. The yolk was then transferred to a sheet of filter paper and rolled about gently until dry; the vitelline membrane was not broken. White and yolk were analyzed separately, each became the object of a general or gross analysis. In addition the various forms of protein in the white were determined, and the fat in the yolk was extracted and studied. Since the fat could not be extracted directly from the liquid yolk by means of petroleum ether in a Soxhlet extractor, the yolk was first coagulated with alcohol, then extracted in the usual way. In like manner a technic was devised for the determination of the number and species of organisms in both the white and yolk.

An article upon the chemical composition and bacterial content of fresh eggs has already been published, and further studies of various phases of the egg industry are now in progress.

Fresh eggs of the Barred Plymouth Rock and White Leghorn breeds were studied separately. The eggs were laid by well-fed hens, the Plymouth Rock during September, October, and March; the Leghorn during February and March. "It is of interest to note that for these well-fed hens there is practically no difference in composition between Fall and Spring eggs."

Practically no difference in the chemical composition of the white was found between fresh Leghorn and Plymouth Rock eggs. Although the gross composition or general analysis of the yolk was influenced but slightly by either breed or individual

FIG. 7.



Candling eggs commercially in a packing house. The operator is holding the eggs before the view-holes of the electric egg-candle. The bucket at his feet is for the reception of "rots" and "spots." The scientific principles of this form of optical apparatus are discussed in Part I of this paper, JOURNAL OF THE FRANKLIN INSTITUTE, June 1911, clxxi. 593.

samples, yet the yolk fat of both breeds was subject to wide variations in the values of the fat constants. Organisms were usually present in both white and yolk of these fresh eggs. "In the 57 experiments 18 had a decidedly greater number of bacteria in the yolk; 11 had the majority in the white and 21 had an almost even distribution; 7 were sterile." From 100 eggs, 36 species of bacteria, 3 varieties of molds and 2 varieties of yeast were isolated.

The commercial methods for the transportation and refrigeration of eggs have already been described in a previous publication of this laboratory.[1]

It is interesting to note that the chemistry of the egg received attention during the early days of American science. On May 19, 1794, John Redman Coxe presented to the Provost, the Trustees and Medical Faculty of the University of Pennsylvania, for the Degree of Doctor of Medicine, "An Inaugural Essay on Inflammation," in which he states, on page 30, that the experiments made by himself and others "prove that portion of air which we always find in one end of the egg to be oxygenous gas."[2]

CONCLUSION.

Modern science is showing a decided trend toward the conservation of natural resources—animal, vegetable and mineral—and of the public health. In this work of conservation, the various scientific bureaus of the Federal Government all have a part; the work of a few of these bureaus may be briefly reviewed. The Public Health and Marine Hospital Service of the Department of the Treasury guards the health of the nation. In the Department of the Interior several bureaus are engaged in conservation; the Reclamation Service carries out the work of irrigation; the Geological Survey studies mineral resources and water resources; and the Bureau of Mines has a two-fold function, the conservation of mineral wealth including fuels, and the conservation of life among mine workers, *i.e.*, the causes and methods of prevention of mine accidents. In the Department of Agriculture the work of the Bureaus of Animal Industry, Forestry, Plant Industry, and Chemistry, among others, is in large part one of conservation. Thus the Bureau of Animal Industry carries out the meat inspection law, and stamps out contagious diseases of animals, such as the recent outbreak of hoof-and-mouth-disease in Pennsylvania and neighboring States. The Forest Service labors for the conservation of the timber supply. One phase of the work of the Bureau of Plant Industry is the study of the vegetable food supply. New vegetables are introduced; and methods of handling the vegetables and fruits already raised in this country are studied, so that they may pass from the producer to the consumer with least loss from decay or deterioration in quality during their journey. This work is illustrated by the investigation on the marketing of citrus fruits.

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[1] Pennington, *U. S. Department of Agriculture, Bureau of Chemistry, Circular No. 64,* 1910.

[2] The Library of the University of Pennsylvania contains a copy of Coxe's Essay, printed at Philadelphia by R. Aitken & Son, 1794.

The Bureau of Chemistry enforces the Food and Drugs Act and carries out various investigations in the fields of bromatology and pharmacy, among which is the work of the Food Research Laboratory. The work of this laboratory has been described in the preceding pages. The course of perishable animal foodstuffs is followed from the producer to the consumer; during these studies the hearty co-operation is secured of packers, railroads, commission merchants, and retail dealers. The various problems which arise are solved by the application of the research methods of the physical sciences—chemistry and physics—and the medical sciences—physiological chemistry, bacteriology and histology. The various factors which influence the keeping qualities of perishable foodstuffs during their marketing are studied in detail; and methods are discovered which will improve the quality of the product as it reaches the consumer, and which will reduce the loss in marketing to a minimum. This is truly conservation of the nation's food supply!

BIBLIOGRAPHY.

The contributions from the Food Research Laboratory which have served, in large part, as the basis of Parts I and II fall into four divisions:

I.—Papers on Poultry. *Yearbook of the United States Department of Agriculture,* 1907, 197–206. *U. S. Department of Agriculture, Bureau of Chemistry, Bulletin No. 115,* 1908, 57–107. *Premier Congrès International du Froid, Rapports et Communications,* Paris, 1908, II, 216–260. *Journal of the American Chemical Society,* 1910, xxxii, 561–568, 568–572. *U. S. Depart-*

ment of Agriculture, Bureau of Chemistry, Circular No. 61, 1910; Circular No. 64, 1910; Circular No. 70, 1911. "The Keeping Quality of Poultry," by Pennington. Address made at the Annual Meeting Missouri Carlot Shippers of Eggs, Butter and Poultry, March, 1910. Published by the Association. Secretary's office, St. Louis.

II.—Papers on eggs. *Journal of Biological Chemistry,* 1910, vii, 109-132. *Seventh International Congress of Applied Chemistry,* London, 1909, *Section* vii. *Agricultural Chemistry,* 228.

III.—Paper on milk. *Journal of Biological Chemistry,* 1908, iv, 353-393.

IV.—Papers on fats. JOURNAL OF THE FRANKLIN INSTITUTE, 1909, clxviii, 365-384, 421-456; 1910, clxix 23-54. *Seventh International Congress of Applied Chemistry,* London, 1909, Section viiic. *Bromatology,* 268-271.

NOTE.—Part I, "The Function and Equipment of the Laboratory and a Résumé of the Researches Carried Out Therein," appeared in the JOURNAL OF THE FRANKLIN INSTITUTE, June, 1911, clxxi, 585-598. Part III, "Select Methods of Analysis" will appear in an early issue of the JOURNAL.

Gasolene Electric 'Bus for London. (*Amer. Mach.,* xxxiv, 785.)—A new type of motor bus is about to be introduced in London, of the combined gasolene-electric type. Two independent 12 horsepower, four-cylinder gasolene motors each drive, through an electric "dynomotor" and a flexible shaft, one of the rear wheels of the vehicle. When the load is light, the excess power of the engines is absorbed by the dynamotors, as dynamos, to charge a special 560 pound storage battery. When the load is heavy the dynamotors are automatically changed into electromotors, and assist the engines, taking power from the batteries. By this arrangement not only are the starting and control much smoother and quieter, but by the more constant load on the engines, the fuel economy is improved. The vehicles, including the wheels, are constructed of steel.

Magnolia Antifriction Metal. (*Amer. Machinist,* xxxiv, 798.)—According to the *Brass World,* the proportions used to make Magnolia metal are lead 80 pounds, antimony 15 pounds, and tin 5 pounds. The analysis shows lead 78.27 per cent., antimony 17.81 per cent., tin 3.88 per cent. and copper 0.04 per cent. The copper is present as an impurity.

Sulphur and Sulphuric Acid in the United States. (*Oil, Paint and Drug Rep.,* May 1, 1911.)—A report of the Geological Survey Department shows that the output of sulphur in the United States has risen from 3147 tons, valued at $88,100, in 1900, to 239,312 tons, valued at $4,432,066 in 1910. The United States still imports some sulphur, but exports about the same amount. A little comes in from Japan, but the business is not well established. A large quantity of sulphuric acid is now made by the copper smelters, and in one case at any rate, the acid output in more profitable than the metal produced. The demand for sulphuric acid exceeds the supply from sulphurous ores and pyrites. In 1909 about 250,000 tons of pyrites were mined and nearly three times as much imported. There are large deposits of pyrites in New York, Virginia and California. The great sulphur deposits in Louisiana now yield immense quantities of commercially pure sulphur.

The Durability of Welded Steel Pipe. H. N. SPELLER. *Eng. News,* lxv, 347.)—Wrought iron pipe seems to have no advantage over steel as regards corrosion. It is believed there is as little occasion for corrosion in pipes and tools around boilers, and in hot water systems, as there is for smoke from a modern power plant. It is thought the problem will be solved by the removal of the oxygen dissolved in the water. The water is heated to a temperature high enough to expel all air, and then passed through an economizer, designed like a closed feed water heater, in which the excess of heat is absorbed by the cold feed on its way to the heater. A continuous supply of air-free water is thus obtained for service lines at any desired temperature.

Oil Fields of Japan. (*Petroleum,* vi, 829.)—According to an official Japanese publication, "Mining in Japan, Past and Present," the oil fields extend from the western coast of Sachalin in the north, through the western part of the central highlands of Hokkaido, and along the coast of the Sea of Japan, then traverse the provinces of Mutsu, Ugo, Utzen, Echigo, and Shinano, and reach the coast of the Pacific Ocean in the province of Totomi in the south. The annual output of crude petroleum has increased enormously in 20 years; in 1888 it was only 45,000 barrels and increased gradually to 1,727,300 barrels in 1907. Each barrel contains 42 gallons. This rapid development is chiefly due to the introduction of the American method of boring in 1890. The province of Echigo produces about 99 per cent. of the total output, and more than 90 per cent. of the Echigo output comes from the three oil-fields of Higashiyama, Nishiyama and Niitsu. Recently the oil industry has been concentrated among a few large companies and individuals. The oil deposits are found exclusively in the tertiary formation, and the strata consist of an upper layer of loam and clay, sandstone and conglomerates; a middle layer of sandy loam mixed with sandstone; and a lower layer consisting mostly of sandstone and clays, with tufa and sandstone at the bottom. The oil bearing strata consist of sandstone and tufa between layers of clay, and sometimes of clay only. The usual depth of the borings is from 600 to 1200 ft. The oil is transported from the wells to the refineries mainly by pipe lines, though some producers still use carts or boats.

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

NECROLOGY.

Mr. Francis Schumann, M.E., C.E., was born in Thuringia, Saxony, in 1844. He was the son of Carl F. W. Schumann, States Advocate and Professor of Jurisprudence in the University of Jena. The family moved to America in Mr. Schumann's childhood. He took up engineering and served throughout the Civil War as Topographical Engineer on Meade's staff. Later he became engineer to the Treasury Department at Washington, a position he held for some years. He then became manager of the Phoenix Iron Works at Trenton, N. J., which position he resigned to found the Tacony Iron and Metal Co., of which he was president and manager. He was engineer in charge of the construction of the City Hall tower, all the work for which, including the statue of Wm. Penn and the smaller groups were cast at Tacony. In addition many of the United States coastwise lighthouses were built under his direction. Mr. Schumann later became president of the Penna. Iron Works Co., a position he retained until his retirement.

He was past president of the Philadelphia Engineers Club, a charter member and first president of the American Foundrymen's Association, president the American Wire Glass Co., vice-president of the Tacony and Pelham Trust Companies. He was a member of the American Society Mechanical Engineers and of the Franklin Institute.

Mr. Schumann was well known as a writer upon engineering subjects, having written several books and a number of monographs, his "Heating and Ventilation" being still a standard work.

For the last five years of his life Mr. Schumann was an invalid. He leaves a widow and one son.

CORRESPONDENCE.

1600 Hamilton St., Phila., June 22, 1911.

The Editor,
The Journal of the Franklin Institute,

Dear Sir:

In a review of "Recent Progress in Metallurgy," printed in the Journal of the Franklin Institute in November, 1906, I called attention to the novel utilization of blast-furnace slag by the United States Steel Corporation in the manufacture of true Portland cement in the following words, "Officials of the United States Steel Corporation are forming a number of subsidiary concerns to the new Indiana Steel Company at Gary, Ind., which will become potent factors in the general operation of that new industrial centre when all is completed. One of the most significant and interesting of these, that has taken form, during the last week, is to be known as the Universal Portland Cement Company. It has a capital of $1,000,000 and its plans, while only vaguely outlined thus far, are understood to contemplate the manufacture of slag cement out of the furnace slag coming from the new blast furnaces to be built in the new town. . . . This will give the corporation a practical cement for all purposes with only the bare cost of making it. The saving will be enormous, as there is no investment for cement deposits, nor for much of the machinery that is necessary for the manufacture of the ordinary rock cement. The raw material is a pure waste, and passing through a process of extraordinarily short duration of time becomes a product of great commercial value. The plant is understood to be one of a number that will eventually be put up. Some may be built in Pittsburg, where they can take over the slag from the scores of blast furnaces of the corporation in this vicinity."

The foregoing information was credited to a then recent issue of *The Manufacturer* and further information was obtained from other sources in corroboration which may be found in the JOURNAL of November, 1906.

Prior to that time a certain quantity of slag cement called "Puzzolan" had been made and used for hydraulic work, or for setting under water, but this was entirely different in its properties from Portland cement.

Since the year 1906 the manufacture of Puzzolan has practically ceased while the production of Portland cement from blast-furnace slag has increased in a truly amazing manner. As evidence I enclose a paper which I think is worthy of being reprinted in the JOURNAL OF THE FRANKLIN INSTITUTE.

It will be observed that the first record of production of Portland cement made from a waste product (slag) of blast furnaces appearing in the table accompanying the paper was in the year 1900, when a total quantity of 32,443 barrels was made. In 1905 the production was 1,735,343 barrels, while in 1910 it had increased to 7,001,500 barrels. This was 1,349,234 barrels more than the total output of Portland cement in the United States in 1899! Remarkable indeed is this record, but still more so is the growth of the Portland cement industry from less than one million barrels in 1895 to more than seventy-three million barrels in 1910. The great increase in consumption has been accompanied by a correspondingly large reduction in cost of production, the reduction in cost causing the increase in consumption.

Had I ventured, in my address before the Metallurgical Section of the Institute in October, 1906, to predict that, in four years time, the production of the Universal Portland Cement Company from blast-furnace slag would exceed seven million barrels of Portland cement I would have been regarded as a dreamer.

Yours very truly,

ALEX. E. OUTERBRIDGE, JR.

THE UTILIZATION OF BLAST FURNACE WASTE.*

By Edward M. Hagar.

Until the last decade, practically the only utilization of the wastes or by-products of a blast furnace was the use of a portion of the waste gases to raise the temperature of the incoming blast through heating the brickwork in so-called hot stoves, and in some cases a small portion of the power value of the gases was obtained by burning them under boilers to generate steam for driving the blowing engines.

At the present time the calorific value of the waste gases is being utilized directly in gas engines for blowing purposes and for generation of electric power; a considerable portion of the slag is used in the manufacture of Portland cement, and the flue dust, consisting of the finest ore and coke particles, is being collected and converted so as to be rechargeable into the furnaces.

The aggregate saving or profits resulting from these three developments is a matter of millions of dollars per annum, and in a modern blast furnace plant, it would almost seem that pig-iron was the by-product; and, indeed, the investment in the equipment to utilize these former wastes, exceeds that of the blast furnace itself.

USE OF BLAST-FURNACE GAS.

The writer, in his work, has come in contact with these evolutions, with plants in operation, or under construction, of a capacity to produce 12,000,000 barrels of Portland cement per annum from slag and limestone, using over 1,300,000 tons of slag in a year, these plants being driven entirely by electric current generated by gas engines directly from the waste blast furnace gases, the power requirements being 40,000 horsepower for 24 hours every working day. In one of the cement plants the first commercial method for reclaiming the flue dust was discovered.

By using the blast furnace gases directly in combustion engines, after suitable washing to remove the grit, the power obtained from a given amount of gas is equal to at least two and one-half times that obtainable by burning the gas under boilers for generating steam for use in steam engines.

A modern blast furnace of the usual size, with gas blowing engines, and gas engines driving electric generators, will provide sufficient gas to furnish 7000 kilowatts electric power, in addition to driving its own blowing engines. This permits the most modern steel works, such as those at Gary, Ind., to practically do away with the use of coal for power purposes, operating the rolling mills by electric power from the surplus gases.

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* Presented before the Congress of Technology at the fiftieth anniversary of the granting of the charter of the Massachusetts Institute of Technology, and reprinted from *The Iron Trade Review*, June 22, 1911.

FLUE DUST.

The United States Steel Corporation, of which the Universal Portland Cement Co. is a subsidiary, has already installed 250,000 horsepower of gas burning and gas electric units, which, it can easily be figured, displaces or saves the consumption of approximately a million tons of coal per annum as compared to the old-fashioned methods.

With the modern high blast pressures, and the use of fine Mesabi ore, the finest of the particles, together with the coke dust, are blown out through the top of the furnaces and are caught in the flues, dust catchers and gas washers. The iron ore in this dust amounts to fully 3 per cent. of the total ore charged, which aggregates the large amount of approximately 1,250,000 tons per annum in this country. Until within a few years, this dust has been thrown away or used as filling, although containing about 40 per cent. metallic iron. For many years, efforts were made to use this material by compressing it into briquettes, but the cost of the operation, together with the fact that the briquettes disintegrated and the dust was again blown out, led to an abandonment of the briquetting plants.

The first commercially successful method of utilizing the dust was discovered by passing the material through the cement kilns of South Chicago. Experiments showed that with the proper heat treatment, the coke dust could be burned off and the iron ore conglomerated into nodules or nuggets averaging over 60 per cent. iron content. These nodules, when fed to the blast furnace, were easily and completely reduced. The fact that the sinter of the flue dust contains such a high percentage of iron and that all of the sinter is reduced, together with its physical shape assisting the steady movement of the charge downward in the blast furnace, thereby preventing so-called slips, makes the sinter more valuable per ton than any ore.

It was necessary to devise mechanical means for preventing the accumulation of the sinter in the walls of the kiln. Plants have been in operation for some years using this process, with endless chains carrying scrapers constantly passing forward through the kiln, and cooled in water on their return outside of the kiln. Recently other methods of utilizing dust have been devised which may prove successful commercially, and the indications are that within a short time the greater portion of this former waste will be prevented.

PORTLAND CEMENT INDUSTRY.

The development of the Portland cement industry in this country and the extension of its uses have been marvellous, and the accompanying table shows a remarkable increase in the production of Portland cement in the United States every year since 1895, when this country first reached the production of approximately 1,000,000 barrels.

It may be of interest to note the increasing percentage of the total American production shown by Universal Portland cement, which is the only Portland cement manufactured in this country using slag as one of the raw materials. With the new plant now approaching completion the aggregate production of Universal Portland cement in the Chicago and Pittsburg districts will amount to over one-eighth of the country's total. Expressed in weight, the output of the finished product will be over 2,000,000 gross tons per annum. Our plants in the Chicago district will consume all the available slag that is suitable for the purpose from an aggregate of 19 blast furnaces in the South Chicago works of the Illinois Steel Co. and in the Gary works of the Indiana Steel Co.

Comparing the pig-iron production and Portland cement production of this country in figures of long tons, the percentage of Portland cement to pig-iron in 1890 was six-tenths of one per cent., in 1900 10.3 per cent. and in 1910 47 per cent. The continuation of any such relative growth would mean that before 1920 the tonnage of Portland cement would considerably exceed that of pig-iron. I would hesitate, however, to predict that such would be the case.

In this country Portland cement is manufactured from a number of raw materials, which, with a few exceptions, may be classed under four heads:

First—Argillaceous limestone (cement rock) and pure limestone.
Second—Clay or shale and limestone.
Third—Clay or shale and marl.
Fourth—Slag and limestone.

In the manufacture of Portland cement from slag and limestone, the molten slag flowing from the furnaces is granulated by a stream of water, loaded into cars and transported to the cement plants, where it is dried in rotary driers, and receives the first grinding; it is then mixed in automatic weighing machines, with the proper proportion of ground and dried calcite limestone. These are then ground together and burnt to a hard clinker at a temperature of nearly 3000 degrees Fahr., rotary kilns, using pulverized coal for fuel.

This clinker, after seasoning, is crushed and ground and mixed with a small percentage of gypsum to regulate the setting time. The cement is ground to such fineness that 96 per cent. passes through a sieve having 10,000 meshes, and 80 per cent. passes a sieve with 40,000 meshes to the square inch. It is then conveyed to the stock house for storage prior to shipment.

FURNACE FLUX.

It is necessary to use as a flux in furnaces supplying slag for cement manufacture, a pure calcite limestone. The limestone burnt with the slag must also be a pure calcite stone. It is also essential that the ores used be of a uniform and proper character.

Inasmuch as Lake Superior ores are noted for their remarkable uniformity of analysis, the resultant slag obtained from the use of these ores and a pure calcite limestone, is more uniform in its analysis than any form of natural clay deposit used in the manufacture of Portland cement, and the variation in the proportions of the two raw materials used in the manufacture of Portland cement from slag is less than those of any other materials mentioned.

The rotary kiln commonly used ten years ago was 60 feet long and 6 feet in diameter. This has gradually been increased in length and diameter, until the modern kiln is 140 to 150 feet long and 8 to 10 feet in diameter, and there are a few even larger kilns in use. Kilns are usually set at an incline of three-quarters of an inch to the foot. With the lining and contents the modern kiln weighs 150 tons, and in revolving upon two bearings presents interesting constructional features.

BUFFINGTON PLANT.

In the case of the plant at Buffington, Ind., using 26,000 horsepower, situated between South Chicago and Gary, Ind., electric power is supplied at 22,000 volts from the steel works at these points. Each piece of machinery is driven by its individual motor, supplied with alternating current at 440 volts. The high tension line is connected through the cement plants, and the gas engines at these two steel works, 14 miles apart, operate continually in parallel. This enables the cement plant to draw its power from either source, or from both sources at the same time, as may be desirable. It has happened that one of these works has supplied power to operate the cement plant and furnished additional power at the same time to the steel works at the other end of the line.

True Portland cement in which slag is used as one of the raw materials, should not be confused with Puzzolan or so-called *slag cements,* which are simply mechanical mixtures of slag and slaked lime ground together without burning. Such cements are suitable only for use underground and in moist locations. The manufacture of Puzzolan cements in this country has practically been abandoned.

The remarkable growth of the Portland cement industry is not equalled by any other manufactured article. This is due to the economy, durability, and plasticity of cement and concrete work. While large engineering work, such as dams, bridges, and heavy reinforced concrete buildings, consume large quantities of cement, the bulk of consumption at the present day is in a multitude of small uses. It takes an average shipment of only five barrels a day to take care of the average customer of a large cement company. For example, there is a steady increase in the application of cement to new uses on the farm, such as silos, fence posts, barn floors, feeding floors, watering troughs, corn cribs, etc. There, as elsewhere, concrete is rapidly displacing all forms of wood construction, this process being hastened by the continually advancing cost of lumber.

CEMENT PRODUCTION OF THE UNITED STATES.

Year.	Production of Portland cement of United States, barrels.	Production of Universal Portland cement, barrels.	Percentage of Universal to total American production of Portland cement.
1895	990,324	....	....
1896	1,543,023	....	....
1897	2,677,775	....	....
1898	3,692,284	....	....
1899	5,652,266	....	....
1900	8,482,020	32,443	0.39
1901	12,711,225	164,316	1.29
1902	17,230,644	318,710	1.85
1903	22,342,973	462,930	2.08
1904	26,505,881	473,294	1.78
1905	35,264,812	1,735,343	4.92
1906	46,463,424	2,076,000	4.55
1907	48,785,390	2,129,000	4.36
1908	51,072,612	4,535,000	8.89
1909	62,508,461	5,786,000	9.27
1910	73,500,000*	7,001,500	9.52

* Government estimate.

BOOK NOTICE.

LEÇONS SUR L'ÉLECTRICITÉ, Professées a l'Institut Électrotechnique Montefiore. Par Éric Gerard, Directeur de cet Institut. Eighth edition, entirely reset, two volumes, paper covers. Vol. I.—Elements of Electricity and Magnetism, Electrometry, Theory and Construction of Electric Generators, xii, 975 pages, 9½ x 6½ inches with 458 figures. Price 12 francs. Vol. II.—Transformers, Transmission Lines and the Distribution of Electrical Energy. Applications to telegraphy and telephony, to lighting, to the production and transmission of motive power, to traction, to metallurgy and to industrial chemistry. 990 pages, 9½ x 6½ inches with 489 figures. Price 12 Francs. Gauthier-Villars, Paris, 1910.

The distinguished author of this voluminous treatise needs no introduction to American readers, an early edition having been translated into English in 1897. Since that time, it is evident that the growth of the work has not suffered from neglect in keeping abreast with the constantly increasing scope and elaboration of the subject. Covering the entire field of electrical engineering, that the work is not even more voluminous speaks highly for the discrimination shown in treating the component topics.

The work combines the desirable qualities of the analytic method of the physicist with the material procedure of the engineer. Fundamentals are treated at length and, without attempting to exhaust any one particular department, each is treated with a degree of thoroughness only excelled in special monographs. As is already well known the author's presentation is at once precise and lucid and even the student who knows only "college" French, will find profit in keeping it readily accessible.

PUBLICATIONS RECEIVED.

Handbook for Iron Founders issued by the Frodair Iron and Steel Company, Limited. 155 pages, 16mo, cloth. London, Company, no date.

Improved Cast Iron, How to Get it in the Foundry. Lecture Delivered to the British Foundrymen's Association (Scottish branch) at Glasgow, on December 10, 1910, by John F. P. Lewis (of the Frodair Iron and Steel Co., Ltd.) 15 pages, 12mo. London, Oliver & Co., no date.

A Systematic Handbook of Volumetric Analysis; or the Quantitative Determination of Chemical Substances by Measure, Applied to Liquids, Solids and Gases. By Francis Sutton, F.I.C., F.C.S. 10th edition, revised throughout with numerous additions, by W. Lincolne Sutton, F.I.C., and Alfred E. Johnson, B.Sc. 621 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Co., 1911. Price $5.50.

Recherche pratique et exploitation des mines d'or. Par Georges Proust, ingenieur civil. 110 Pages, illustrations, 12mo. Paris, Gauthier-Villars, 1911. Price, in paper, 2 francs, 75 centimes.

Elektrochemische Umformer (galvanische Elemente). Von Johannes Zacharias, ingenieur. 262 pages, illustrations, 12mo. Wien, A. Hartleben's verlag, 1911. Price, in paper, 4 marks.

Les Lampes Électriques. Par H. Pécheux, docteur ès sciences. 186 pages, illustrations, 12mo. Paris, Gauthier-Villars, no date. Price, in paper, 50 cents.

U. S. Bureau of Mines, Bulletin 12. Apparatus and Methods for the Sampling and Analysis of Furnace Gases. By J. C. W. Frazer and E. J. Hoffman. 22 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

U. S. Bureau of Mines, Bulletin 14. Briquetting Tests of Lignite at Pittsburg, Pa., 1908–9—with a chapter on sulphite pitch binder. By Charles L. Wright. 64 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1911.

U. S. Coast and Geodetic Survey. Results of Observations Made at the Coast and Geodetic Survey Magnetic Observatory near Honolulu, Hawaii, 1907 and 1908. By Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 95 pages, plates, quarto. Washington, Government Printing Office, 1911.

Tobin Bronze. Descriptive pamphlet. The Ansonia Brass and Copper Company. 35 pages, illustrations, 16mo. Ansonia, Conn. October, 1908.

U. S. Department of Agriculture, Office of Public Roads, Circular No. 94. Progress reports of experiments in dust prevention and road preservation, 1910. 56 pages, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Agriculture, Forest Service, Bulletin 88. Properties and Uses of Douglas Fir. Part 1, Mechanical Properties. Part 2, Commercial Uses. By McGarvey Cline, Director, Forest Products Laboratory, and J. B. Knapp, Assistant District Forester. 75 pages, illustrations, plates, map, 8vo. Washington, Government Printing Office, 1911.

CURRENT TOPICS

The Cause of Internal Corrosion of Hot Water Pipes. M. J. Falkenburg. (*Eng. News*, lxv, 347.)—The return pipes in the heating system of a modern office building corroded seriously with a few months service. Apparently the cause was traced to the presence of zinc, and probably the black iron return pipes were manufactured from billets to which scrap metal containing zinc had been added, and the mass heated only hot enough to roll and not enough to volatilize the zinc. The scale on the corroded pipes contained 0.3 per cent. zinc, the condensed water near a corroded place contained zinc oxide and carbonate, and the original pipe between 0.2 and 0.4 per cent. zinc. There was no zinc in the steam risers, which showed no corrosion; and there was no evidence of serious corrosion in the pipes of another building heated from the same source.

Chemical Action Induced by Cathode Rays and Canal Rays. E. P. Perman. (*Chem. Soc. Proc.*, xxvii, 94.)—The transmutation of copper, thorium, and uranium by means of cathode rays and canal rays has been attempted and the chemical effect of canal rays has been studied. The conclusions are: (*a*) Neither cathode nor canal rays cause any transmutation of elements. (*b*) Canal rays in air or oxygen have a strong oxidizing action. (*c*) The oxidizing action appears to be mostly direct, but is accompanied by a scattering effect. (*d*) Many substances are decomposed by the action of canal rays independently of the nature of the gas in which the rays are produced.

Flaming Arcs. Edit. (*Elec. Rev. West. Elec.*, lviii, 322.)—The slow progress in the adoption of this type of illuminant is probably due to the "inertia" of purchasers. It should be used extensively on account of its high operating efficiency, the agreeable color of the light, the large area of the source, and its even distribution. Flaming arcs should always be mounted at least 20 feet from the ground, and often better results are obtained when as high as 40 feet. The power of penetration possessed by flaming arc rays makes them valuable in shops where there are clouds of vapor obscuring the light.

Platinum, the Most Precious Metal. Anon. (*Electrical Rev.*, lviii, 579.)—Platinum is becoming scarce. Its chief source is the Ural Mountains of Russia. About one per cent. of the total supply is found in the United States and small quantities in Canada and

Columbia. Recent prices are $43 per oz. for hard metal and $41 per oz. for soft metal. This is rather more than twice the price of gold, which is $20.67 per oz.

Preventing Corrosion of Metals by Electricity. ANON. (*Elect. Rev. West. Electr.,* lviii, 326.)—According to a recent Australian invention, the galvanic action of corrosive substances in water may be neutralized by sending weak electric currents to the metals to be protected. Tests made at Melbourne University on metals immersed singly and in connected pairs in hot and cold sea water, and in dilute acids, showed that all destructive galvanic action was suspended by a small expenditure of electric power.

Cost of Water Waste. ANON. (*Eng. Record,* lxiii, 374.)—Most people do not recognize that, at New York City water rates, the small drip of a leaky faucet wastes annually from $2 to $6 worth of water; or that the cost of a leak flowing from an orifice 1/32 inch in diameter, under a pressure of 39 lbs. will amount to $11 or $12 annually on a meter rate basis. Hence it is necessary to correct the idea that a small leak is too insignificant to warrant attention.

Packing Machinery for Export. F. H. DAVIES. (*Amer. Mach.,* xxxiv, 927.)—The careful packing of machinery for export is very essential in securing export business. Goods should be packed so as to be able to withstand careless and rough handling, to keep out moisture, to resist the attacks of insects and vermin. Yet care should be taken that it is no heavier than is necessary. All marking should be in simple language and in plain letters and figures. This article will be found worthy of close attention by exporters.

Safety of Oil as Liquid Fuel. (*Amer. Mach.,* xxxiv, 890.)—It has been shown that oil with a flash-point of 239°F. will not ignite if fired into with a shell, and if dynamite is exploded in a reservoir of this oil, it only throws up jets of oil which do not ignite. The only dangerous liquid fuel oils are those which have not parted with their volatile, inflammable gases; such as absolutely crude oils. In all ordinary, commercial, fuel oils, these portions are removed, and the oil is safe and contains no power of spontaneous combustion. Oil with a fire-test of 180° to 200° F. is as safe as coal, and it will not ignite when stirred with a red-hot poker, nor when hot coals are thrown in it.

A New Highly Active Radium Preparation. A. FISCHER. (*Pharm. Post.,* xliv, 193.)—At the Neulengbach radium works, a crude radium sulphate is obtained directly by a combined extraction process; the acid and alkaline fusion. Ten thousand kilos of pitchblende residues can be treated in this way, and crude radium chloride obtained in 6 weeks, and low grade ores, containing 3, 6, 10 to 15 per cent. of uranium oxide, which cannot be treated by the Curie-Debierne process, are available for radium manufacture. Experiments on living skin showed that radium emanation enters the organism mainly by inhalation. The Neulengbach works furnishes preparations which in sterile sodium chloride solutions exhibit activities up to 300,000 Mache units.

Temperature Measurements in an Experimental Carborundum Furnace. H. W. GILLETT. (*J. of Phys. Chem.*, xv, 213.)—This is an extensive inquiry into the forms of pyrometer which may be used for the accurate determination of temperatures from 1700°–2500°C. in a carborundum furnace. Three instruments were used: (1) a Wanner pyrometer, specially sensitized; (2) a Morse Thermoguage (Holborn-Kurlbaum pyrometer) with improved calibration; and (3) a specially improved form of Thwing radiation pyrometer; all these being calibrated against a spectrophotometer. Working with the three pyrometers, the temperature of the formation of siloxicon was found to be 1540°C. ± 30° C., that of carborundum 1820° C. + 20° C., and the decomposition temperature of carborundum was 2220° C. ± 20° C.

Explosions of Compressed Air. W. L. SAUNDERS. (*Eng. and Mining J.*, xci, 713.)—Compressed air may easily become charged with inflammable vapors, through using in the compressors lubricants with too low a flash-point; or if the pipe lines are not regularly drained at low points, where oil, etc., is liable to accummulate. Cases have occurred where pipe lines have been shattered through the ignition of such accummulations of inflammable vapor, probably by heating due to compression. For this reason the use of kerosene to clean air pipes is condemned. These accidents can be avoided by regular inspection of the interior of the compressors and of the whole system of compressed air.

Automobile and Gas-Engine Lubricating Oils. F. SCHWARZ AND H. SCHLÜTER. (*Chem. Zeit.*, xxxv, 413.)—Several oils, some of which had proved suitable and others unsuitable in practice, were examined for their density, viscosity and flash-point, but these determinations gave no indication as to their suitability. In the case of cylinder oils, which must not leave a residue in the cylinder and should not give an objectionable odor to the exhaust, it was found that extraction with acetone at the ordinary temperature removed the noxious constituents of the oil. From 66 to 93 per cent. of the oil was insoluble in acetone, and had a higher flash-point and ignition-point and a lower density and viscosity at 20° C. than the original oil. Hence the proportion insoluble in acetone is a rough measure of the suitability of a cylinder oil.

Change of Structure of Aluminum. H. LE CHATELIER (*Comptes rend.*, clii, 650.)—Some aluminum articles underwent spontaneous disintegration, and on examination showed that in each case a cellular structure had developed, and that the disintegration was evidently due to the opening of the joints between the cells. Laboratory experiments indicated that the presence of small quantities of calcium were probably the cause of the development of this cellular structure.

Anticorrosive Alloy. G. JACQUIER, Johannesburg. *Eng. Pat.*, 20601 of 1910.—This anticorrosive alloy has the composition aluminum 92 per cent., bismuth 2, copper 5 and silicon 1 per cent.; or of aluminum 91 per cent., bismuth 2, copper 5 and magnesium 2 per cent. The metals except the aluminum are melted together, and then the molten aluminum added.

Coffee Glazes Containing Arsenic. F. E. NOTTBOHM AND E. KOCH. (*Z. Unters. Nahr. Genussm.*, xxi, 288.)—Shellac is one of substances used for glazing coffee beans, and attention is drawn to the fact that shellac is sometimes colored by arsenic trisulphide. Samples of shellacs were found to contain from 0.0785 to 0.12 per cent. of arsenic, while samples of colophony were free from arsenic. Coffee beans glazed with arsenical shellac were found to be strongly contaminated with arsenic.

Two New Compounds of Stannous Chloride and Ammonia. A. J. SOFIANOPOULOS. (*Comptes rend.*, clii, 865.)—Persoz found that stannous chloride, heated with dry ammonia gas, gave a compound with the formula $SnCl_2NH_3$. The author finds that this compound is produced in the cold, even below 0° C. A compound with the formula $SnCl_2.2NH_3$ is formed by passing dry, cooled ammonia gas over a shallow layer of well dried stannous chloride in a large glass tube, cooled by a mixture of ice and salt. Ammonia is passed until the contents of the tube are of a uniform light yellow color. This product should be kept in a colored bottle, shaded from light. A third compound, $3SnCl_2.2NH_3$, is formed by the action of gaseous ammonia on stannous chloride at a temperature between 120° C. and 300° C. It is a reddish-brown crystalline mass, powerfully double-refractive, and is apparently the most stable of the ammonia and stannous chloride compounds.

Colored Etching of Steels. F. ROBIN AND P. GARTNER. (*Rev. Mét.*, viii, 224.)—The polished specimens are etched in a saturated solution of picric acid for thirty seconds, and it is claimed that on rinsing them in water and then allowing them to dry without wiping, a variety of colors are produced, by which the various constituents, such as austenite and martensite, may be distinguished. The original article is illustrated with microphotographs.

Spectrum of an Electrically Heated Carbon Rod. M [illegible] ROSA. (*Ann. Physik.*, xxxiv, 222.)—When a carbon rod of 2 [illegible] mm. diameter is heated white hot by a current of 15–18 an[illegible] per square mm. passed through it, it is surrounded by a layer of incandescent gases, the spectrum of which was investigated. It consists of a faint continuous background on which a number of bands or lines are seen. The bands are those of the Swan spectrum, with faint traces of the so-called cyanogen spectrum, while the lines are those of the metallic impurities found in the carbon. When the rod is heated in pure nitrogen (after all occluded gases are removed) no metallic lines appeared, and scarcely any trace of the cyanogen bands, while those of the Swan spectrum (presumably due to carbon vapor) were seen better than when the rod was heated in air. This, and similar experiments, show that oxygen is necessary for the appearance of the metallic lines. The explanation suggested is that in the hot carbon rod the metallic impurities form carbides, which are broken up only by oxygen, thus leaving the metal free to radiate.

The Use of Storage Batteries for Electroplating. G. M. HOWARD. (*Brass World*, vii, 89.)—Due to its steady high voltage the lead battery is particularly well suited for plating work, and is superior to low voltage dynamos. Storage batteries may be used as a regulator for a dynamo. As auxiliaries they are superior, two batteries being alternately charged and discharged. Systematic attention is necessary for storage batteries. The principles of the operation are summarized.

Nitrification by the Ultra-Violet Rays. D. BERTHELOT AND H. GAUDECHON. (*Compte rend.*, clii, 522.)—An aqueous solution of ammonia, after being exposed for a few hours to the action of ultraviolet rays in the presence of oxygen, gave all the reactions for nitrites. The oxidation appears to be arrested at the nitrite stage, for no nitrates were detected. The same result occurs when air is substituted for oxygen. The production of nitrites was observed in solutions of ammonium carbonate, ammonium chloride and ammonium sulphate under similar conditions, but much more slowly in the two latter cases where the amount of hydrolysis is small. Solutions of urea and several primary and secondary amines are decomposed with the liberation of ammonia. Nitrates exposed to the rays are degraded to nitrites. A solution of ammonium nitrate gives nitrite with evolution of nitrogen and oxygen, showing that the nitrite is produced both by oxidation of the ammonium group and the deoxidation of the N_2O_8 group. The formation of nitrites is also detected in solutions of potassium nitrate. There are many points of resemblance between the action of these ultraviolet rays and that of certain micro-organisms.

The Melting of Carbon by the Joule Effect. M. LA ROSA. (*Ann. Physik*, xxxiv, 95.)—Moissan concluded that carbon cannot be melted except at high pressures. The author made experiments which indicate that at least incipient fusion can be attained. Heavy electric currents up to 90 ampères were passed through small carbon rods of 1 to 3 mm. in diameter. If the current was increased at once to the highest amount, the rod usually exploded violently, partly on account of the liberation of occluded gases, and partly on account of the sudden expansion of the rod. When the current was applied more slowly, the rod sometimes bent under its own weight. From this effect and from the appearance of the particles of the exploded rods, the conclusion is reached that carbon has partially melted. Since especially purified carbon, containing less than 0.08 ash was used, it is considered that the fused appearance of the rods could not have been due to the presence of impurities.

The Formation Temperature of Carborundum. H. W. GILLETTE. (*J. Ind. Eng. Chem.*, iii, 242.)—The decomposition point of silicon carbide into graphite is found to be 2220° C. ± 20° C.; the formation of crystalline silicon carbide occurs at 1820° C. + 20° C., and the formation of siloxicon at 1540° C. ± 30° C. A description of his furnaces and of the apparatus for measuring the temperature is given.

On the Duration of the Phosphorescence of Uranous Salts. J. BECQUEREL. (*Mon. Scient.*, lxxiv, 347.)—It is known that the duration of phosphorescent light is longer as the temperature is lower. Lenard has shown that three phases can be recognized; the hot phase, in which the emission is proportional to the excitation (fluorescence); the permanent phase, when the emission is prolonged after excitation; the cold phase, which is a storing up of the luminous energy, without any emissions. The three phases change gradually from one to the other. Certain uranous salts show a remarkable property; even at the extremely low temperature of the solidification of hydrogen (—259° or 14° absolute) they show hardly any other phase than the hot phase. The examination in the phosphoroscope of uranous salts cooled in liquid nitrogen (—193°) and then held at the ordinary temperature, gives the following results. A certain number of salts, principally organic, acetates, tartrates, oxalates, follow the general law; at a low temperature they have a notably longer phosphorescence than at the ordinary temperature; at —193° some even remain luminous for several seconds after removal from the tube of the phosphoroscope. On the other hand the uranous sulphates and the nitrate show no change in the duration of the emission. Different properties of the uranous salts lead us to think that the mechanism of phosphorescence can be localized in the radical uranyl, UO_2. In spite of the variability shown by certain salts, the constancy of the duration of the phosphorescence in the other compounds, is quite in accord with this hypothesis. It remains to be shown if this phenomenon persists with the same stability at the lowest temperatures obtainable.

The Expansion and Physical Condition of Water. J. DUCLAUX (*Journal de Physique*, Feb., 1911.)—A large number of empirical formulas have been proposed to represent the expansion of water, for a given interval of temperature. Most of them are either very complicated, or are only exact between very circumscribed limits of temperature. Duclaux presents a formula which agrees with the experimental data for a long interval, from —10° C. to + 150° C., and has besides a simple theoretical significance. According to Röntgen, at ordinary temperatures, water may be considered as a solution of ice, that is to say, that it contains polymerized molecules, probably identical with those of the solid ice. These polymerized molecules are lighter than water, and the volume of liquid is increased by their formation. The lower the temperature the more numerous they become. The maximum density of water is well explained by this hypothesis: when water is cooled below 4° C., the non-polymerized molecules contract. But on the other hand the number of polymerized molecules increases. It is easily conceived that the resultant of these two opposing forces can cause an increase in volume. Duclaux's proposed formula comprises two terms; the first of the parabolic type, $a + bt + ct^2 + \ldots$, would represent the expansion of a liquid constituted solely of simple molecules. The second term takes into account the expansion of volume due to polymerization; it is almost proportional to the number of molecules of ice, and is well expressed by

$$K.\ 10^{\frac{n}{T}}$$

where K and n are constants and T is the absolute temperature. This becomes then

$$v = a + bt + ct^2 + K.\ 10^{\frac{n}{T}}.$$

This formula agrees with experimental results, when suitable values are given to the constants. The measurements of Thiesen, Scheel, and Diesselhorst, are very accurately represented, when

$$\begin{array}{ll} a = 0.991833, & 10^6 c = 2.84475, \\ 10^4 b = 2.25208, & 10^6 k = 0.53977, \end{array} \quad n = 1143$$

Further, the theoretical reasons which lead to a formula of this type for water, are equally applicable to all liquids with linked molecules (alcohols, organic acids, and probably mercury at low temperatures). It is probable then that the expansion of liquids can be best represented by analogous expressions.

The Presence of Zinc Nitride in Zinc Powder and in the Zinc of Commerce. C. MATIGNON. (*Comptes rend.*, clii, 1309.)—Briegleb and Geuther have shown that zinc heated to low redness in a current of nitrogen, becomes covered with a gray powder, which prevents the agglomeration of the metallic filings even when raised above their fusion point. Zinc covered with this gray powder disengages a little ammonia when fused with potassium hydroxide. It has been observed that zinc fixes nitrogen most rapidly at about 600° C., under these conditions zinc containing nearly 10.6 per cent. of nitrogen has been obtained. It is certain that in the majority of cases the quantity of nitrogen contained in 1 k.g. of commercial zinc does not exceed 30 to 40 mg. Zinc nitride seems to exist in all commercial zinc powders; it is also found in some zincs, but in extremely small quantity. Zinc white (oxide) does not contain any.

The Clancy Cyanide Process. ANON. (*Eng. Mining Jour.*, xci, 904.—This is the practical application of the process as now installed at the Ajax mill, near Victor, Col. It is conducted in two stages: (1) The generation of a cyanogen halide, usually cyanogen iodide, which attacks the sulpho-telluride minerals, dissolving them with the gold; (2) the regeneration of the cyanogen by the reaction between calcium cyanimide and the thiocyanates and alkali cyanates. The apparatus consists of the usual fine grinding and cyanogen equipment, a low voltage direct current generator, a cyanimide solution tank, and an electrolyzing apparatus which is hung in the agitating tanks in use. The anodes are of fused magnetite and are hung in pairs between the cathode sheets which consist of iron plates. The surface area of each anode is 2.2 square feet. The anode is closed at the lower end, and the upper end is cemented into a porcelain cap, which insulates the anodes from the frame and protects the copper connections from the solution. The cathode is insulated in a similar manner. The current density varies, being generally about 18 ampères per square foot of anode surface. The difference of potential is about 7 volts and a current of about 50 ampères is passed through each anode.

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AN EXPERIMENTAL STUDY OF VORTEX MOTIONS IN LIQUIDS.

BY

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It is not improbable that the first observer of vortex motions was Sir Walter Raleigh; if popular tradition may be credited regarding his use of tobacco, and probably few smokers since his day have failed to observe the curiously persistent forms of white rings of tobacco smoke which they delight to make. But some two hundred eighty years went by, after the romantic days of Raleigh and Sir Francis Drake, who made tobacco popular in England, before a scientific explanation of smoke rings was attempted.

About 1867 Professor P. G. Tait translated into English a most important mathematical paper by the German physicist Von Helmholtz. In this paper Helmholtz submitted to a rigid mathematical analysis the motions and the properties of vortices in an assumed perfect fluid, that is a fluid without viscosity. Tait's translation, which appeared in the Philosophical Magazine, immediately attracted the attention of Lord Kelvin, who saw in the results of the analysis of Helmholtz a possible explanation of the ultimate constitution of matter.

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Tait illustrated the several points of the Helmholtz argument by some cleverly devised experiments with smoke vortices. He provided a large cubical box with a round hole in one side and a flexible diaphragm on the opposite side. Ammonium chloride fumes were generated in the box to provide the smoke. When the flexible side of the box was struck sharp blows, symmetrical and swiftly moving rings issued from the hole opposite. These possessed many of the curious properties which Helmholtz had predicted for the vortices in a perfect fluid. They had integrity of form and moved swiftly forward always in a line normal to their plane, and carried with them the same material with which they issued from the box. They seemingly possessed elasticity of form such that striking slanting-wise an object or another ring, they were thrown into violent vibrations, as if they had been hollow anchor rings of rubber or similar material. If a swiftly moving ring was made to follow close behind a more slowly moving one, the forward ring was overtaken and this, as the other approached from behind, would accommodatingly expand and allow the approaching ring to pass through it. The ring now in advance would then be overtaken by the first ring and in turn would expand to allow this to overtake and pass through it, the speed of the approaching ring having been increased by an apparent attraction, as between the rings.

These experiments were witnessed by Lord Kelvin who was deeply interested, and the ideas suggested he rapidly developed into his famous vortex theory of matter, in which the ultimate particles of matter are postulated as consisting of indestructible vortices in the ether. Essential to this theory is the supposition that a vortex filament of circular or other form, knotted or interlinked with another filament, would, if once created in a perfect fluid, endure forever. It might vibrate, encounter obstacles, expand or contract, but it could not be cut or broken into parts. Motion, whirling, rotary motion, about an axis or line closed upon itself, was the essence of its entity. According to Kelvin, one portion of space contains matter, if the ether in that space possesses vortex motion, while another portion of space is without matter if the ether in that space is not possessed of vortex motion. The atoms are vortices and are eternal.

In the many scientific memoirs which Kelvin wrote during this period, this novel view of a kinetic constitution of matter was supported with consummate skill.

It seems strange, however, that though the laws of vortex motion were exhaustively examined by the ablest mathematicians of the time, few if any experiments were made to study vortex motions in air and fluids, beyond the first experiments with smoke rings above referred to.

Finally with the discovery of radium the entire scientific world, including Kelvin himself, adopted the more fruitful ideas regarding the constitution of matter, which have become crystallized in the modern " electron theory."

That few experiments were tried appears the more astonishing, when it is considered that we have at our disposal such high density fluids as water and oils with free surfaces and small viscosity, in which beautiful vortex motions may be easily produced in great variety and of curious forms.

The experiments which are about to be described would, if made earlier, have possibly had a greater interest as bearing upon Lord Kelvin's ingenious theory of the vortex atom.

However, consider the electron which modern theory substitutes for the vortex atom. Calling it an elemental unit negative charge of electricity is but giving a name to something whose ultimate nature is as obscure as the hard atom of Lucretius made somewhat more thinkable by the Kelvin hypothesis.

The first crude experiments were of a kind such as to be reproducible with slight effort and little or no expense. In the center of the cover of a baking-powder tin a round hole, about 1 cm. in diameter is made. This is filled with water colored with red or black ink and covered. Care must be used to fill the tin completely so that no air remains. A porcelain bath-tub makes a most convenient water tank. This is filled nearly full and the tin, with its colored water, is submerged at one end of the tub. The tin is held horizontally in the left hand while a sharp blow is struck by means of a hammer in the right. A perfectly symmetrical vortex ring, somewhat greater in diameter than the hole in the tin, will be expelled and travel to the far end of the tub, reaching it in about a second. This production of visible rings may be repeated until the water in the tub becomes clouded with ink.

Two interesting properties of these rings may be tested at once. If the tin is held so that the ring grazes the side of the tub, it is, on touching the side, broken up and scattered, but if it be pointed so that the ring goes, not at too great an angle, toward the surface of the water, it is, on reaching or nearly reaching the surface of the water, reflected down from the surface. The angle of reflection is equal to the angle of incidence, and the ring preserves both its form and velocity. The plane of the ring always maintains itself perpendicular to its direction of motion, hence when reflection occurs the ring tilts its plane through an angle.

The experiments first made in this way seemed to promise a line of interesting investigation, if properly constructed apparatus was made and methods devised for the production of the rings under conditions that could be completely controlled and modified in various ways.

It was decided to construct a suitable outfit for making a series of qualitative observations of the properties of the rings and then, if it should prove possible, to take instantaneous photographs of them. Both plans were executed successfully and the outfit and methods employed will now be described in sufficient detail so that any one, who wishes to reproduce the apparatus and experiments and take photographs, may do so.

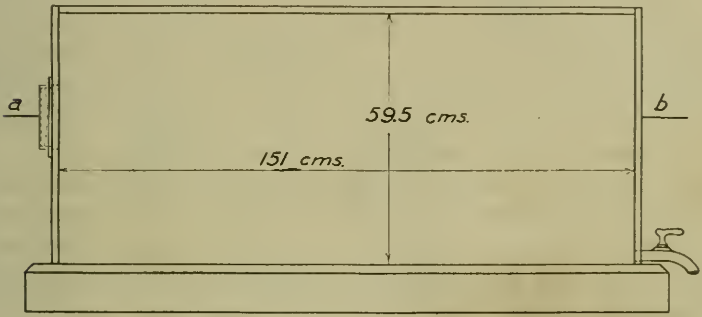
DESCRIPTION OF APPARATUS FOR PRODUCING LIQUID VORTICES.

It was recognized at once that a tank was required which would permit the rings to be observed from the side, the top, and the end. Furthermore, for continuous experimenting, the rings must be colored with a material which, when the rings break up, would entirely disappear and leave the water of the tank clear, for otherwise the tank would require repeated refilling.

Fig. 1 shows clearly the construction and dimensions of the tank used. The bottom and ends were of wood and the sides of clear plate glass 7 mm. thick. Its inside dimensions were—length 151 cms., height 60 cms., and width between inside surfaces of the plate glass 12 cms. In one end was mounted a lens 10 cms. in diameter, through which one could see with a clear focus almost to the far end of the tank when it was filled with water. In the end opposite to the lens, close to the bottom, there was a spigot for emptying the tank. The pressure of the liquid against the glass sides made them bulge out dangerously and removable brass straps were required to hold them together at the top.

The method of shooting the rings and the construction of the "gun" received much consideration, and after two years' experience with the first form constructed, no single detail seems to need change. An electro-magnet was used to produce the impacts upon the flexible metal diaphragm of the gun. The choice of an electro-magnet proved, later on, to be a wise one when the rings were being photographed, as the timing and force of the blow could be precisely regulated.

FIG. 1.



Section on: a – b.

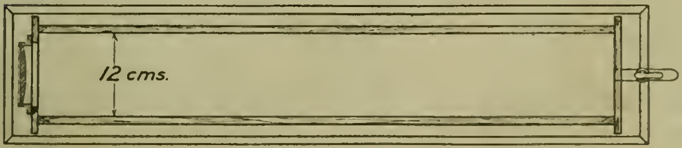


Diagram of tank.

The gun was supported on brass rods in such a manner that it could be aimed in any desired direction by adjustments made above the water. The hole in the front end of the gun from which the rings issue could be closed or opened by means of a hinged metal piece which also was operated by a brass rod above the water. The gun proper consisted of a short cylindrical brass tube 7.7 cms. in diameter and 6.6 cms. long. On the front end of this tube was a removable disk of brass held in place against a shoulder with thumb screws. Disks were provided with holes of various shapes and sizes, and some with more than one hole. The flexible diaphragm in the back end of the tube was of phosphor bronze, well hammered to be springy.

The electro-magnet, for producing the impact upon this diaphragm was in the form of a split hollow anchor ring and of the same diameter as the tube. The armature was on the side opposite the tube and consisted of a disc of soft iron with six radiating fingers. The winding lay in the hollow of the anchor ring and was embedded in wax. Access of water to the winding was further prevented by covering the open end with thin sheet brass. A rod was fixed to the centre of the armature normal to its face and, passing through the centre of the magnet, struck the diaphragm a sharp blow on the magnet being energized. The length of stroke was about .6 cm. The armature was returned to its original position by means of a spiral spring, after deenergizing the magnet. The winding was of No. 28 double silk covered copper wire and had a resistance of 17.5 ohms.

An important feature in the construction was a small thumb screw at the extreme front end of the tube and located on its upper side. After the tube had been filled and put under the water in the tank this screw was removed, and the last bubble of air made its escape. The complete removal of air was found to be essential to the formation of the best rings.

As the success of the experiments was largely dependent upon the construction of the gun, a complete working drawing of it is shown in Fig. 2.

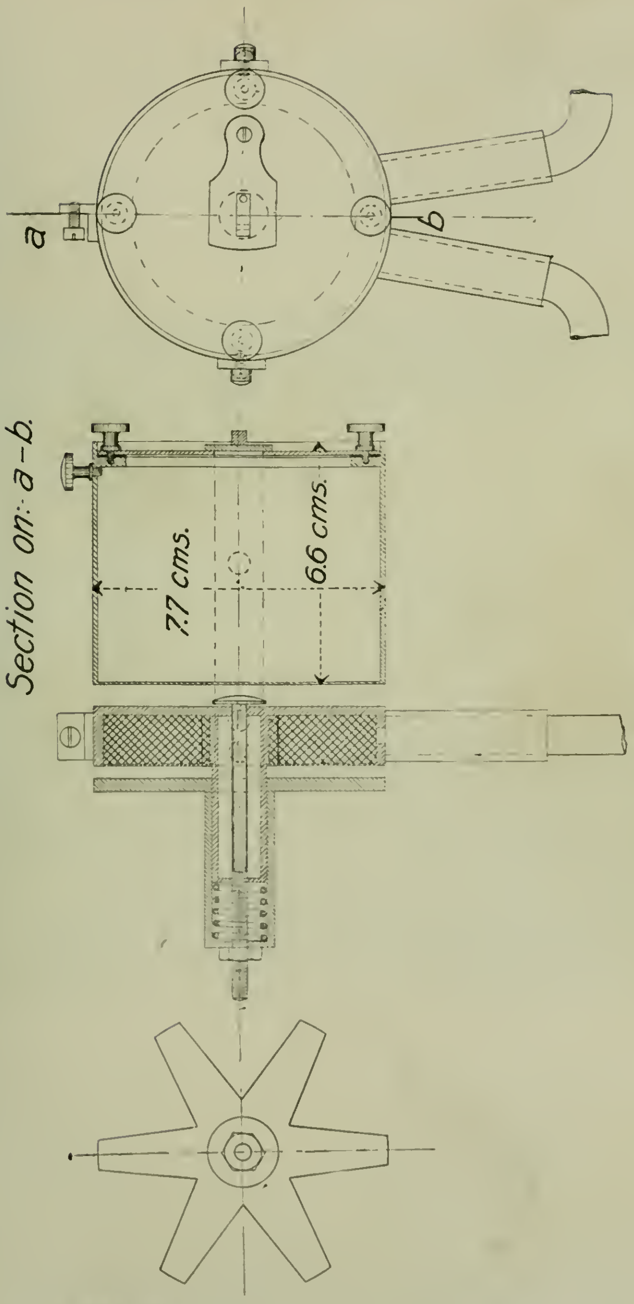
As in some of the experiments it was required to note the effect of the collision and close passage of rings approaching each other from the same and from opposite directions, two guns were constructed. When their magnets were joined in series, rings could be ejected from the two guns at the same instant.

The entire apparatus including that employed for photographing the rings, is shown in Fig. No. 3 reproduced from a photograph.

The gun was operated from a source of direct current of 110 volts. As the circuit through the gun magnet could be closed only for an instant, a switch was devised so that by pulling a trigger the circuit could be made and quickly broken again. As this switch may be of use in other connections where a circuit carries a large current for a brief time, and as it is simple in construction it is shown in Fig. 4.

The rod of metal, bent down at each end and supported at its middle point on a fulcrum, has one end in a cup of mercury

FIG. 2.

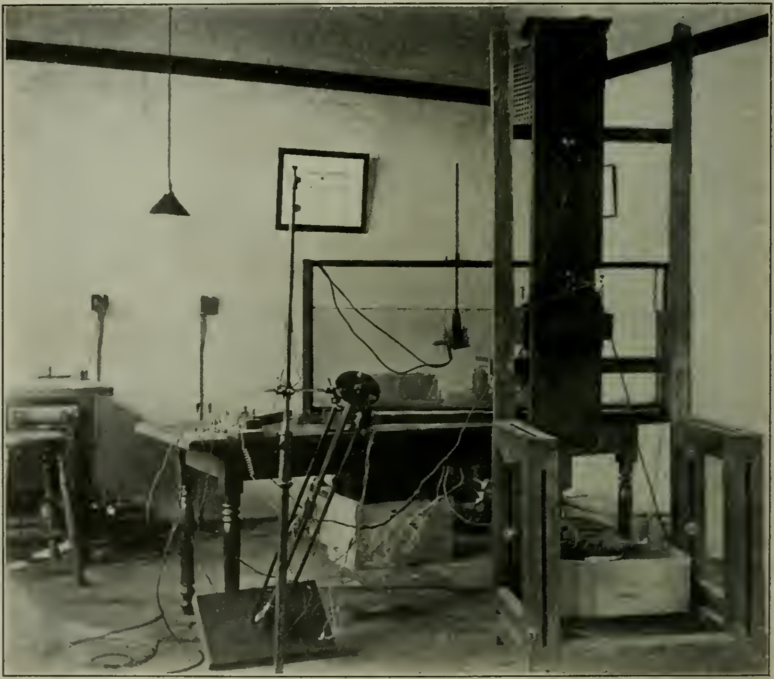


Working drawing of gun.

while in its initial position, and the other end in another cup of mercury when in its final position, to which it is drawn by a spring when a catch is released. Only when the rod is horizontal is each end in a mercury cup, thus closing the circuit from mercury cup to mercury cup.

This switch, together with a rheostat, was used in circuit with the gun and 110 volts. As the gun is under water a current of 10 or more amperes could be passed through the winding for a brief time without overheating. The plunger could, therefore, be made to give a very hard blow upon the flexible diaphragm and eject a ring at high velocity, and possessing considerable energy.

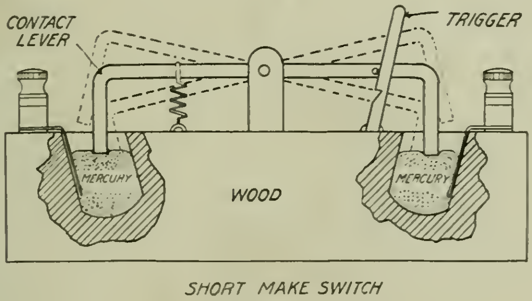
FIG. 3.



Photograph of outfit.

The problem of making deeply colored rings, which could be easily observed or photographed, but which on breaking up would leave the water perfectly clear, was successfully solved for rings of a deep red color and of a milk white color. For the red rings phenol phthaline was used. This substance is, as purchased, a white powder. To prepare it for use, a teaspoonful is dissolved in ethyl alcohol, just enough being used to dissolve it. This solution is then diluted with about two litres of pure water. It is then colorless or slightly milky in appearance. About a tablespoonful of strong ammonia is then added which turns the solution to a deep, rich red color. This is put in the gun. To the water of the tank, while it is being filled, to get good mixing, is added about an ounce of strong hydrochloric acid. The gun is placed in position in the tank and the last bubble of air is allowed to escape. The connections of the electric circuits are then made, when the apparatus is ready for shooting rings.

FIG. 4.



Gun switch.

A ring when shot goes the length of the tank and preserves its form and color until it strikes the glass or end of the tank. When the ring breaks up the acidity of the water entirely destroys the red coloring matter of the ring, leaving the water of the tank perfectly clear, even after a hundred or more rings have been ejected. It was customary to refill the gun, however, after shooting about twenty-five rings, as they gradually grow paler.

For making milk white rings an emulsion of chloride of silver was used which also becomes colorless in a weak solution of ammonia. To make such an emulsion, which will not settle even after standing over night, a tablespoonful of clear gelatine should be boiled in a litre of water until completely dissolved; then mix with this about 15 grams of silver nitrate crystals, which have been previously dissolved in water. Then add a weak solution of hydrochloric acid, stirring well, until the nitrate is all precipitated as chloride. Care should be observed not to use an excess of acid. The result is a smooth, milk white solution which will not settle, and will turn quite colorless in very weak ammonia water. This solution can be half diluted with water. The tank should be filled with weak ammonia water and the gun with the solution. Beautiful milk white rings can then be made in the same manner and with the same ease as red rings, and a large number may be shot without any clouding of the tank water.

SIMPLE QUALITATIVE EXPERIMENTS.

By means of the brass rod which supports the gun, and the rod which tilts it in a vertical plane, it may be quite accurately pointed in any desired direction. By applying 110 volts directly to the magnet, the ring which issues from the gun will go the entire length of the tank in about one-half second, and the gun may be aimed so that it will hit the lens at the far end of the tank fairly in the centre. When the ring is near the lens it begins to expand, and will increase, at the moment of striking, to several times its original diameter. The ring is best observed end on through the lens as it approaches. It is seen to be about 1.9 cms. in diameter, or 1.5 times the diameter of the hole in the tube. Its form is quite symmetrical and resembles a small anchor-ring. The diameter of the solid portion is about 3.1 mm. and the hole in the center is between 12 and 13 mm. When observed through the glass at the side, the path of its motion is seen to be straight and its velocity gradually diminishes as its distance from the gun increases.

It should be particularly observed that the same material, the colored water which leaves the gun, moves bodily from one end of the tank to the other. It is thus possible to project for a distance of over a meter rings of a strong alkaline solution through a solution strongly acid. If the water of the tank contains suspended particles of slightly greater density than water, the ring will pass through and among them without incorporating and carrying them along with it. Thus sifting Indian meal into the water in the path of the ring it was found that none of the particles of the meal were taken up by the rings.

Another pretty experiment in this connection is to hold in the path of the ring chiffon cloth stretched over a frame when it will be found that the ring passes easily through it without being broken up or disturbed in its motion.

The kinetic energy of these rings is considerable. If a piece of tissue paper similarly stretched, be held in the path of the ring, the ring will break through it, but in turn is broken up by the impact. If a light watch-chain hangs in the water, and is fairly struck by a ring, it is bent into a decided curve by the force of the blow. This power of the ring to bend a chain was used to advantage in some of the later photographic work when timing the ring and the drop of a photographic plate.

If a gun is placed at each end of the tank and two rings are shot simultaneously in opposite directions it is observed that, if they meet fairly, both are broken up and dissipated; but, if their line of approach is such that they might be expected to touch on their edges on coming near together, they bend out of a straight course and pass without an encounter or injury to their form.

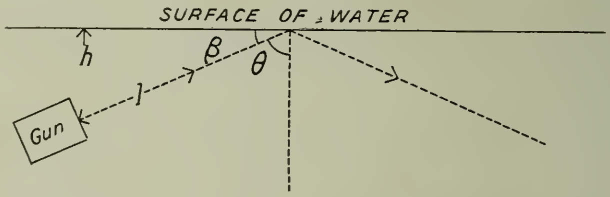
The swiftly moving rings described above may have their speed reduced as much as desired by inserting resistance in the gun circuit. The slowly moving rings are easier to observe and may be quite as perfect in form as the more rapidly moving ones, and for many experiments it is better to make slow rings, but as they move with less contained energy the phenomena of impact, deviation from the straight path, when approaching one another, and the vibratory phenomena are less marked and less well defined.

When the gun is tilted so as to shoot a ring toward the surface of the water it is, on reaching the surface, reflected in a very beautiful manner. As the surface of the water is approached the upper edge of the ring gains a little in velocity over the lower edge, so that the plane of the ring tilts through an angle, equal to the change in direction of the line of approach to the surface. In other words, the plane of a moving vortex ring is always maintained normal to its direction of motion. As near as could be judged from observations, the laws of reflection are the same as those of light rays. It sometimes happens that a ring approaches the surface of the water when this is disturbed by a wave motion and is not level. Under such circumstances the angle of reflection may appear quite different than the angle of incidence--but this is probably due to the indeterminateness of the latter angle. There is a certain critical angle which the line of approach of the ring to the surface makes with the normal to the surface of the water, at which the ring will not reflect but jump out of the water with a spurt. The results of four carefully made trials to determine the value of this critical angle are given in the subjoined table. The diagram, Fig. 5, accompanying the table makes clear the meaning of the symbols used. We have, $\sin\beta = \frac{h}{l}$, hence $\beta = \sin^{-1}\frac{h}{l}$.

Trial	h cms	l cms	sin β	β	Θ
1	16.2	44.5	.364	21°, 21′	68°, 39′
2	30.3	78.3	.387	22°, 50′	67°, 10′
3	34.2	82	.417	24°, 40′	65°, 20′
4	9.3	25	.372	21°, 50′	68°, 10′

It is possible to produce refraction of the rings as well as reflection. To accomplish this the tank is half filled with water and then with a rubber hose a dense solution of salt or barium-chloride is carefully siphoned into the tank at the bottom so as to make a layer of liquid denser than water underneath the water.

FIG. 5.



If a high velocity ring be now shot so as to pass at a slight angle from the water into the denser salt solution below, it will be observed to pursue a path which is slightly curved downwards. This experiment was not tried out as carefully as could be desired, but it seems certain that the path of the ring is considerably deflected in passing through media of different densities. It is probable, though no exact measurements were made, that the velocity of the ring diminishes when it passes from the lighter to the denser medium.

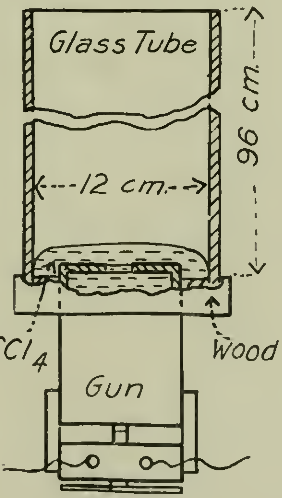
Rings which are ejected from a very exactly circular hole are always round and advance through the water with no other visible motion than that of progression. If, however, the hole in the gun is elliptical, vortices are formed and progress as before, but they assume, in addition to their forward motion, a vibratory motion. The vibrations are such that the vortex changes from an ellipse with its major axis vertical to an ellipse with this axis horizontal. The vibrations are almost too rapid to be followed distinctly with the eye. It is a most interesting sight to observe such a vibrating ring as it moves throughout the entire length of the tank, especially if it is observed through the lens along its line of motion.

Triangular and square holes also give rise to vibratory rings. But the most remarkable property of water rings is observed when the end of the gun is provided with two holes, one above the other. In the experiments tried the two holes were each .85 cm. in diameter with 2.55 cms. between their centres. The two rings, which issue simultaneously from the two holes, begin to attract each other as soon as they leave the gun, and at a distance of about 6 to 8 cms. from the gun they come together with great suddenness and form a single ring of twice the circumference of one of them. The ring so formed proceeds with apparently the same velocity as a single ring to the end of the tank. It has, however, vibratory motions that are remarkable. Unlike the single ring, which issues from an elliptical hole and vibrates in one plane only, the ring formed by the union of two rings has a much more complicated vibratory motion in planes normal, and parallel to the direction of forward motion of the ring. The peculiarity of this motion will be better understood from references to illustrations given later. These vibratory rings will also reflect from the surface of the liquid but it is doubtful if the angle of reflection is equal, always, to the angle of incidence, as the angle of reflection will depend upon the phase of the vibration of the ring at the moment when it reaches the surface.

Novel and unexpected results were obtained when the surface of the water in the tank was covered with a layer of kerosene oil from 5 to 10 cms. deep. To render more apparent any phenomena which might happen the oil was given a deep red color. It may not be generally known that all ordinary dyes and coloring materials will not dissolve in oils but sink to the bottom without imparting to the oil any color. At least 20 or 30 coloring stuffs, including many aniline dyes, were tried before one was found which would impart a color to kerosene oil. Of those tried, two only were found which would color kerosene. One is known as alkanet root and the other is a coloring material known under the trade name of Soudan III. Both materials were tried but the latter is the more satisfactory and imparts to the oil a deep rich red color. It will also color carbon-tetrachloride, acetone, paraffin, all oils and probably many other chemicals, but is entirely without effect on water. A thimbleful of this dye was used to color two or more gallons of kerosene, which was then floated upon the surface of the water in the tank. The gun was located about 30 cms. below the oil and aimed so as to project rings toward the surface of the oil at an angle, adjusted by trial, so that the water-ring would enter the oil. The result was surprising. The water-ring on entering the oil instantly became converted into an oil ring. This oil ring continued to move to the upper surface of the oil, where it was reflected, and moving downward entered the water as an oil ring and continued to move until broken up by its encounter with the end of the tank. The results were, of course, just the same whether the water in the gun was, or was not, colored. With no coloring matter in the water the vortex ring of water was invisible as it approached the oil, and the illusion was given of red oil rings issuing from the oil without any apparent agency for their production. After the ring broke up, the oil of the ring rose to the surface of the water and united with the main body of the oil, and this process could be continued indefinitely. It was, however, necessary to wait about a quarter of a minute between the shooting of successive rings as the surface of separation between the water and the oil required such time to regain its quiet and smoothness, after the agitation caused by the passage of a ring through the surface. It was found that to obtain oil rings in the above manner the angle at which the water rings were projected toward the oil had to be adjusted within rather narrow limits. This adjustment could easily be made, however, after a few trials. If an oil ring was projected with such a velocity that it nearly lost its forward motion before striking the end of the tank, the oil constituting the ring would segregate into small globules. The small globules would continue for a time in rapid circulation about the vortex filament. This rapid movement, in small circles, of the oil globules, in apparent defiance of centrifugal force, was a very striking and interesting phenomenon.

It was thought that in the case of two liquids of different densities, at least if these two liquids were not miscible, it ought to be possible to project a vortex ring of the less dense liquid through the liquid of greater density, as kerosene oil through water; but that it would not be possible to project a vortex ring of the liquid of greater density through liquid of less density, as a water ring through kerosene oil. Such was proved experimentally to be the case. If the gun was filled with kerosene oil, the ring was easily sent the entire length of the tank through water. To test the reverse case a cylindrical glass tube was provided 96 cms. long and 12 cms. in inside diameter. This tube was placed vertically and the gun fastened in its lower end. The particular arrangement employed is shown in Fig. 6.

FIG. 6.



Assuming the reverse to be true, if the gun projected a vortex ring of the denser fluid through the water, the ring should rise to the surface of the water, there break up, and the material of the ring settle down and again join the supply in the gun. Hence the vortex rings might be continually projected up the tube without renewal of the liquid. But unfortunately this was found not to be possible. The denser liquid employed was a mixture of carbon tetrachloride and kerosene oil. This mixture could be given any desired density, slightly less to slightly more than that of water, by varying the relative proportions of the two liquids. The mixture was colored red with Soudan III.

What occurred was this: if the blow on the diaphragm of the gun was light, the red liquid would issue from the hole a short distance as a large, shapeless globule, which, after rising a short distance, would sink back and rejoin the liquid in the gun. If the blow was hard, the liquid would leave the gun apparently starting in the form of a ring but would fly to pieces after going but a few centimeters. The results appear to be the same however the density of the red liquid be varied, so long as the density is at all greater than the water. It was thus conclusively proved that where two liquids are non-miscible, a vortex ring of the denser liquid is unstable in the lighter liquid and can not be projected and preserve its integrity.

To determine whether vortex rings might be made to solidify and to produce solid rings, so to speak, a large earthenware jar was filled to the middle with cold water and from the middle to the top with hot water. The gun was filled with melted paraffin and held in the hot water and pointed vertically downward. In this way liquid rings of hot paraffin were projected through the hot water into the cold water. Upon entering the latter, they at once solidified and preserved their form. In this manner a number of solid paraffin rings were obtained. For the sake of variety the paraffin was in some cases colored red with Soudan III. These rings were quite symmetrical and made very pretty objects.

Numerous modifications were made of the orifice in the gun, from which the rings issued, with a view of finding the most efficient form for the projection of circular rings. In one modification a short tube was inserted in the end of the gun, but it was found that the best and most perfect rings could be obtained from a simple, circular hole in the centre of the front end of the gun. It appeared to make no difference whether the edges of this hole were sharp or not.

It soon became apparent, from these preliminary experiments, that, if the peculiarities of these rings were to be described to others, and, if what happened was to be precisely determined when the rings formed and especially when two rings united, it would be necessary to take photographs of them.

(*To be concluded*)

MACHINE MOLDING.*

BY

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President, Tabor Manufacturing Company.

The art of molding is probably as old as civilization, and it may have reached a high state of development before any of the events which make up ancient history took place. In fact the molders' skill, as exemplified in many antique works of art, has been one of the great civilizing forces of the world, and it may be questioned whether we can produce to-day any finer examples of this art than are to be found among the relics of antiquity. But as civilization has progressed the demand for the products of the foundry has increased to such an extent as to call for new processes, better methods, and greater efficiency. The printing press, the steam engine, the loom, and, more recently, the internal combustion engine, have stimulated the activities of men, augmented their productive capacities and so enlarged the possibilities for commercial intercourse that it is difficult to realize how few of the comforts of life now enjoyed by the masses were within reach of the well-to-do or even the wealthy members of society as it was constituted two hundred or even one hundred years ago. George Washington, for example, began his career as a surveyor; carried with him the bare necessities of life, often slept out of doors on a bed of hay or straw, swam the streams that were too deep to ford, and later on, after enduring innumerable privations and hardships in many hard fought campaigns, laid the foundation for the government which stands as a monument to his sagacity, courage, and determination. There were no Pullman cars for him and no potentate, however great or wealthy, could have travelled a hundred years ago with the luxurious ease now within the reach of very moderate means.

Going back a little further to Columbus, in the height of his glory as the first admiral of what was then the greatest power in the world, we can imagine his quarters on a flagship which was but little if any better in size and comfort than the lifeboat of a modern steamer. In short, since man first began to utilize the forces of nature, so abundantly provided for his material comfort and enjoyment, the productive capacity of the world has increased at a rate which staggers the mind to follow and reduces to nothingness the spells wrought by Aladdin and his wonderful lamp.

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* Presented at the meeting of the Mechanical and Engineering Section, held Thursday, May 18, 1911.

To compare the industrial progress made since the discovery of America with all that went before would be a hopeless task, but it is not hard to believe that the nineteenth century alone surpassed in the development of the arts and sciences all that was inherited from the past and that in all probability the twentieth century will do the same. The present rate of industrial progress is indeed so rapid as to almost defy pursuit, and it is only possible to keep in touch with it in spots where our own special interests are involved.

No man nor set of men can grasp the enormous accumulation of knowledge bound up with advancing civilization, and as fast as the work of yesterday can be recorded the achievements of to-day are almost out of sight. This cannot go on forever at undiminished speed, and it is clearly due to the awakening of man to a knowledge of the natural forces within his grasp. It is accompanied at the same time by the destruction of the resources upon which it feeds and grows, and it will sooner or later be followed by a reaction when posterity begins to descend the slope leading back to the ashes from which so much greatness and power has been derived. A great deal of permanent value will no doubt remain, but with the prospect of exhausted resources before us, however distant that time may be, we may well pause for a moment to consider not only the conservation of natural resources, but also the efficiency of human labor upon which the conversion of our resources into wealth depends. We cannot eat our cake and have it, but we can make it last a long time and enjoy it with more satisfaction if we do not bolt it all at once

But the conquest of nature is not to be halted by sentimental considerations and the consumption of our resources will no doubt go on unabated until their conservation becomes a crying need. Its consideration now as a matter of national importance is one of the most hopeful signs of the times, and, fortunately for all of us, efficiency as well as economy in all the affairs of life is coming into the foreground and receiving more attention than it ever has before.

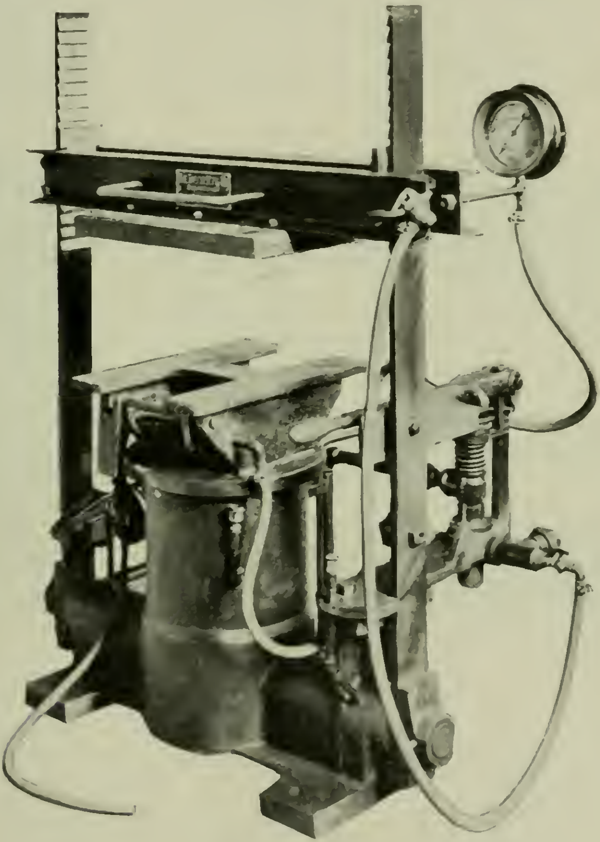
People are beginning to realize that the high cost of living is due chiefly to extravagance and waste, and that there is such a thing as scientific management by which human labor may be conserved and its products enormously increased. When rightly understood and applied this benefits the wage-earner, employer and public as well, and goes a long way toward the solution of the labor problem which is inseparable from the cost of living.

Improvements in machinery, combined with power for its operation, have worked wonders in the output of labor, but only a fraction of what can be realized from the same amount of human effort when more intelligently directed and controlled. The all-round mechanics of former years have well-nigh disappeared and good workmen, if obtained at all, must be recruited from such raw material as can be found unemployed. There is always an abundance of the inefficient kind, and the problem now confronting the manufacturer is how to make it efficient and valuable. The answer to this is to be found in the introduction of an educational system of management not unlike the laboratory system adopted in some of our schools and colleges. Men must not be left to their own devices to pick up such knowledge as may make them inferior or merely good enough workmen. They must be systematically taught to perform the work assigned to them by shop bosses or foremen who are interested in the result, and whose chief function it is to teach. In this way every shop in the country may become in effect a trade school of the most valuable kind, in which the pupils are not only taught how to do certain things but how to do them quickly and well and earn a substantial reward commensurate with the skill attained. No labor-saving machine can produce results without human aid in one way or another, and many a machine, good for its purpose, has been abandoned to the scrap heap, not from any inherent defect or inability to effect a saving, but simply as the result of awkward or inefficient handling. We must have efficient workmen as well as efficient machines to obtain the best results, and foundries need both as much as, or possibly more than any other kind of operating plant to-day.

Although modern industry depends upon the foundry for a large part of its products and the ingenuity of inventors has been busily engaged for generations in the evolution of labor-saving machinery, very little of this effort has been devoted to the improvement of the foundry itself, and it is only within comparatively recent years that machine molding has developed much importance as an art. In the year 1800 an English patent was granted for molding screws, the patterns for which were backed out of the sand by lead screws of the same pitch. This was simply a pattern drawing machine of rather ingenious construction, but the English records do not touch again upon machine molding until 1839, when a very similar patent appears. From this time forward more interest seems to have been aroused and these patents were soon followed by others for packing sand by mechanical means, including hydraulic cylinders, stampers and rollers of the road-roller type. Machines for molding gears and pipes also appear in the first half of the nineteenth century, and in 1843 we find an American patent on the molding of cannon balls. Later, in 1869, the first jarring machine patent was taken out, and it is not proposed to give a history of the art of machine molding from patent office records but simply to point out that the art began in a small way on bench work and continued chiefly in its application to small molds that one or two men could handle until the end of the last century. Larger work was not generally regarded as applicable to machine molding until the jarring machine began to emerge from a long period of obscurity and demonstrate its peculiar fitness for ramming large bodies of sand. Its development for large work belongs mainly to the present century and through its means the art of machine molding has been extended to embrace nearly everything molded in sand. But there are, of course, exceptions and peculiar difficulties which will always depend upon the molder's skill for their proper execution, with or without the aid of machine, and like any other equipment the installation of molding machines must depend upon the saving to be effected by their use and the outlay needed to effect that saving. This leads at once to the consideration of foundry costs, the analysis of which should point the way to their reduction. These costs are made up of many important elements beyond the scope of the subject, and the effect of one item only need be considered, that of machine molding, leaving all other items to be treated in the same way by those who are interested in attaining the highest efficiency in every detail of operation.

Machine molding began, as has been said, on small work and probably one of the best known appliances is the little hand squeezer. This is a very simple and effective machine designed to save part of the time consumed in ramming. Figure 1 is a little power squeezer adapted to the same class of work as the hand squeezer which saved the work of ramming but put upon the operator the work of squeezing. There the man still did the work but with greater despatch, and therefore more efficiently. Here the machine does the squeezing and

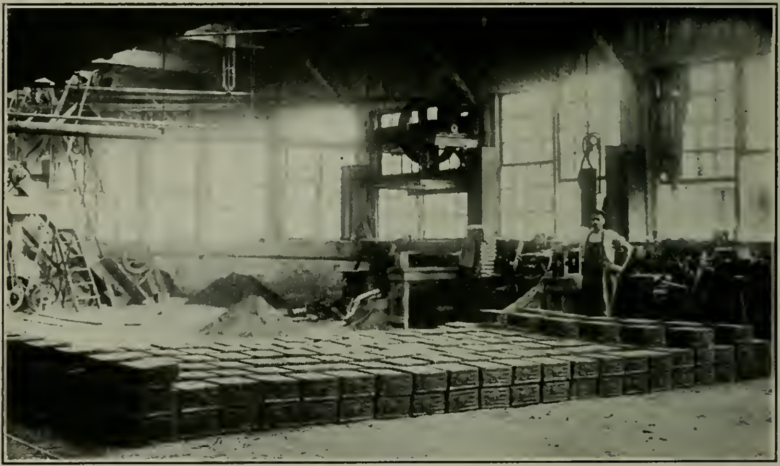
FIG. 1.



the operator is less fatigued and can work faster. In support of this statement the floor shown in Fig. 2 may be offered as evidence.

Here 270 molds have been put down by one man in six hours and it is stated that this daily performance has recently been increased to 325 in the foundry of the American Hardware Corporation, where nearly 100 machines of the same type can be seen at work. Of course these performances by expert operators are not to be expected along the whole line, where the average may be in the neighborhood of 200 molds a day, but they show what is possible, if not always probable, and it remains to be seen how a proper day's work on any given pattern can be fairly estimated. We are frequently asked to say what our machines will do and what production we will guarantee, regardless of the fact that we never know anything about the man operating the machine and seldom very much about the patterns to be used, the cores to be set or the precautions found necessary to insure success in molding the same patterns by hand. We know in a general way the type of machine required, but until we have actually made molds and poured castings, we are at a disadvantage and cannot safely guess at results which should be determined from a careful analysis of the experience gained in molding by hand. The

FIG. 2.



foundryman contemplating the introduction of machines has had the necessary experience, but he seldom, if ever, has it in a shape available for analysis, and the importance of making observations in detail and recording the time required for each and every step taken in the production of a mold will be shown. This has been brought out very forcibly by Mr. Knoepple in the April number of the *Engineering Magazine.* The suggestions there made are in line with the practice of the Tabor Manufacturing Company for the last five or six years, but the matter is one that has only begun to receive the attention it deserves as an important feature of scientific management. Consider, for example, a set of patterns mounted in a vibrator frame 13 inches by 17 inches for use on a squeezer. They can be molded either by hand or by power, but if we mold them by hand and note down the time taken by every step in the process we shall see where to look for a saving and what to expect when molded by power.

Fig. 3 shows the result of observations taken on molding by hand by an experienced man with a stop watch. The time is taken in minutes and hundredths for convenience in summing up. Items 4 to 11 inclusive have to be done in the same way and will consume the same time, .45 minute, whether the mold is made by hand or by power, as will appear in Fig. 4.

Item 12 must be done more thoroughly and takes more time when the mold is completed by hand.

Item 13 is not required for machine molding.

Item 14, butt ramming .30, is equivalent to squeezing by power, but it takes five times as long.

Item 15, striking off, is performed after ramming and takes .03 longer than striking off the unrammed sand on the machine.

Item 16 is not required in machine molding.

Item 17, rolling over, is the same in both cases.

Items 18 and 19 take .14 min. and only .08 min. when compressed air is used on power machine.

Items 20 and 21 are the same for hand or power molding.

Item 22 shows .56 min. by hand against .18 by power.

Item 23 is not done by power as a separate operation

Item 24 is the same in both cases.

Item 25 to rap pattern takes .48 min. against .12 min. to start vibrator and lift cope at one operation on machine.

Item 26 is the same in both cases.

FIG. 3.

DM11

INSTRUCTION CARD FOR OPERATION

SYMBOL

Sheets. Sheet No.		Drawing No. H'nd Mol'g		Order No.
Material	Class No.	Pieces in lot	Time for lot	Bonus

Description of Operation. Molding Drag and Cope. (Part of Plow.)
Shown in Bulletin M. R. January 1st, 1911. (Page 8.)
Flask 13″ × 17″ 4″ Drag, 4½″ Cope Hand Molding at Bench.

Item	DETAILED INSTRUCTIONS	Feed	Speed	Element time per piece	Time for entire lot	Continuous or running time
1	Preparation					
2						
3						
4	Pick up hard sand match and put on bench			0.04		
5	Pick up pattern and put on hard sand match			0.04		
6	Pick up drag and put in place...			0.07		
7	Shake parting on pattern..............			0.08		
8	Pick up riddle and put on flask........			0.02		
9	Fill riddle with sand. One shovelful...			0.04		
10	Riddle sand on pattern................			0.08		
11	Fill drag with sand. Three shovelfuls..			0.08		
12	Pein around edge of drag and butt ram some (with shovel butt).............			0.10		
13	Put two more shovelfuls in drag.......			0.06		
14	Butt ram..........................			0.30		
15	Strike mold off with bar 3/8 × 1 × 36 long			0.10		
16	Pick up bottom board and place in position........................			0 08		
17	Roll mold over......................			0.08		
18	Remove hard sand match..............			0.07		
19	Blow sand off of mold (with bellows)...			0.07		
20	Repeat operations 6 to 10 incl. for cope			0.29		
21	Fill cope with sand. Four shovelfuls....			0.10		
22	Repeat operations 12 to 15 incl. for cope			0.56		
23	Mark sprue hole (with cope board).....			0.05		
24	Cut sprue hole......................			0.12		
25	Rap pattern. Spike going through sprue hole into pattern..................			0.48		
26	Round sprue........................			0.10		
27	Remove cope mold...................			0.09		
28	Blow pattern off with bellows..........			0.09		
29	Draw pattern from mold by hand.......			0.45		
30	Patch up mold (with slick)............			0.30		
31	Close mold........................			0.12		
32	Remove snap flask from mold..........			0.07		
33	Remove mold to floor.................			0.07		
34						
35	Number 4 riddle.			4.20		
36						
37	Weight of shovel, 5 lbs.					
38	Weight of sand, 16 lbs.					
	Total weight, 21 lbs.					

When machine cannot be run as ordered machine boss must at once report to man who signed this card.	4 Month	19 Day	11 Year	Signed DVM Checked

Fig. 4.

DM 11 INSTRUCTION CARD FOR OPERATION SYMBOL

1 Sheets, Sheet No. 1		Drawing No.	Machine No. M 10 32 R	Order No.
Material	Class No.	Pieces in lot	Time for lot	Bonus

Description of Operation. Molding Drag and Cope. (Part of Plow.)
Shown in Bulletin M. R. January 1st, 1911. (Page 8.)

Flask 13″ × 17″ 4″ Drag, 4½″ Cope. Power Squeezer.

Item	DETAILED INSTRUCTIONS	Feed	Speed	Element time per piece	Time for entire lot	Continuous or running time
1	Preparation........................					
2						
3						
4						
5	Pick up hard sand match and put on table of machine........................			0.04		
6	Pick up pattern and put on hard sand match............................			0.04		
7	Pick up drag and put in place..........			0.07		
8	Shake parting on pattern			0.08		
9	Pick up riddle and put on flask....			0.02		
10	Fill riddle with sand.........			0.04		
11	Riddle sand on pattern			0.08		
12	Fill up drag. 3 shovelfuls..			0.08		
13	Pein around edge of drag. (Butt of shovel.)			0.05		
14	Strike off with board and put in place ..			0.07		
15	Bring yoke over and squeeze. 60 lbs. pressure			0.06		
16	Roll mold over. (On table.)			0.08		
17	Start vibrator and remove hard sand match			0.03		
18	Blow off with compressed air			0.05		
19	Repeat operations from 7 to 11 inclusive for cope			0.29		
20	Fill up cope. 4 shovelfuls			0.10		
21	Repeat operations 13, 14 and 15 for cope			0.18		
22	Remove cope board..................			0.03		
23	Blow mold off with compressed air......			0.05		
24	Cut sprue hole......................			0.08		
25	Start vibrator and lift cope............			0.12		
26	Blow mold off with compressed air......			0.05		
27	Start vibrator and draw pattern			0.10		
28	Close mold..........................			0.12		
29	Remove flask................			0.07		
30	Stop off carrier.......................			0.06		
31	Place mold on floor...................			0.06		
32						
33				2.10		
34	Number 4 riddle					
35						
36	Weight of shovel 5 lbs.					
37	Weight of sand 16 lbs.					
38	Total weight, 21 lbs.					

When machine cannot be run as ordered machine boss must at once report to man who signed this card.	4 Month	20 Day	11 Year	Signed DVM Checked

Item 27, remove cope, takes .09 min.

Item 28, blowing off pattern with bellows, takes .04 longer than with compressed air.

Item 29, drawing pattern, takes .35 min. longer.

Item 30, patching up .30 min., is not called for on machine.

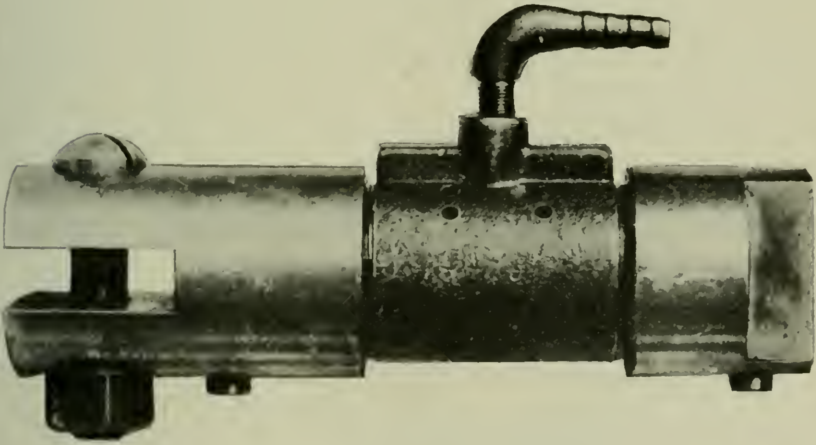
Items 31, 32 and 33 are the same in both cases; in molding by power an additional operation, stopping off carriers .06 min., is required.

Fig. 4 shows the operations in detail for molding the same patterns on the machine. There are thirty operations by hand footing up 4.20 min. and 27 operations on the machine footing up 2.10 min., making the machine time just one-half of the time required when molding by hand without the use of compressed air.

It is also apparent from a study of these time-tables that the use of compressed air alone instead of bellows will effect a saving and that the vibrator in connection with hand molding will also effect a greater saving. Making the necessary substitution in Fig. 3 for the use of blower and vibrator it will be found that this additional equipment alone would reduce the molding time from 4.20 to 3.06 min. It, therefore, appears that the blower and vibrator can be used to save 1.14 min. per mold and the squeezer .96 min. more. This looks as though the blower and vibrator alone saved so much that it might not be worth while to put in the machine, but if we look again at the increased production, taking hand work as the basis for comparison, we see that the output from the use of the former is $\frac{4.20}{3.06}$ or 1.38, while from the use of the latter it is $\frac{4.20}{2.10} = 2$, that is an increase of only 38 per cent. on hand work against 100 per cent. on machine work.

But it may be argued that another element of time remains to be considered, and it must be admitted that no account has yet been taken of the time required to distribute a large number of molds on the floor. I do not know how far a mold can be carried and placed on the floor in .06 min., the time noted, but this time should be taken to about the middle of the space to be covered, and perhaps some additional time should be allowed for this item, but on the other hand it may be said that no allowance has been made for the inexperience of the operator, who was in this case a pattern-fitter and not a molder or demonstrator. The time given will vary with different men, and it was taken in these cases simply for the purpose of illustrating the method by which important conclusions can be reached. No better data can be obtained for fixing prices, and when time is taken by an observer of experience who understands his business the stop watch never runs unless useful work is being done in the right way. A reasonable allowance should always be made for contingencies and a bonus put upon the performance of the work specified in the allotted time.

FIG. 5.



When patterns are cast in an aluminum match plate both cope and drag can be squeezed at the same time, the number of operations on the machine is reduced from 27 to 25 and the total time from 2.10 to 1.76 min.

The snap flasks used are of the usual type, and in these experiments about the same size, in this case 12 inches by 17 inches, 4-inch cope, 4½-inch drag. The machine will squeeze molds as large as 14 inches by 20 inches, but the best production can generally be realized on smaller sizes.

Instead of the aluminum match plate patterns may be mounted on a steel plate, and when split or flat back this is a very convenient method.

They may also be mounted on a paraffined board held in a vibrator frame, and when so arranged the molding time is substantially the same as for the aluminum match plate mounting.

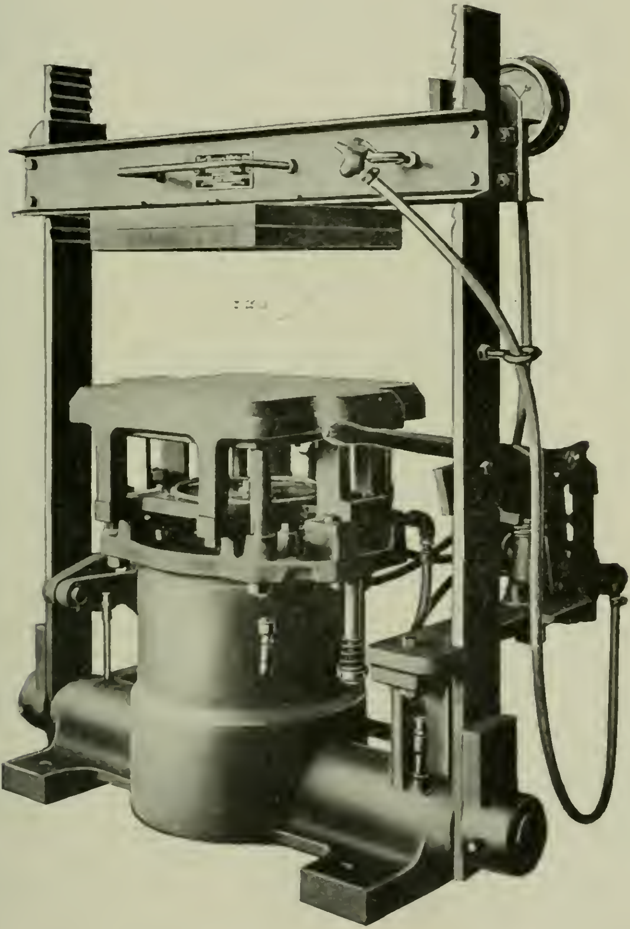
Fig. 5 shows the Tabor vibrator, to which a large part of the saving effected by compressed air, with or without a power squeezer, is due. Power squeezers are made in various sizes, but the smallest size covers by far the largest field. It has been imagined that by increasing the size of flask and putting in more patterns greater production can be obtained, but this is seldom the case, and as previously mentioned the greatest output comes from medium-sized flasks easily handled by one man. Fig. 6 illustrates a small power squeezing split pattern machine with power draft. Machines of this type can be used with or without stripping plates and are applicable to a great variety of work made in solid or snap flasks. There is less handling time on this machine than on the power squeezer, and since each half of the mold is made separately the strain on the operator is not so great.

It is also possible to cope off, by means of supporting stools, pockets of hanging sand that would be impracticable on a squeezer. It is a very fast machine, but no illustration is as yet available to show where it gains on the squeezer by reducing the number of operations required and the total molding time. There are some jobs, however, which can be made as quickly on one machine as on the other, and although this is a much higher class of machine than the squeezer it does not follow that it is better for every purpose.

On such machines the cope and drag are frequently made from the same set of patterns, and it is therefore a matter of first importance to have them so located on the pattern plate as to match perfectly when the mold is closed.

Split pattern machines have been on the market for many years and their value is recognized and appreciated, but unfortunately they have to be built for a flask of fixed dimensions or at least fixed in length or width to fit the flask pins on the machine. They are expensive to build, rather inflexible in their application, and within the last few years they have been superseded very largely by roll-over machines with straight pattern draft to ram by hand or by power. An ingenious hand-ramming roll-over machine, with mechanism for rapping the pattern carrier and dropping the flask from the pattern, was brought out by Teetor in 1889, in which plated patterns are carried in a roll-over frame to which the flask is clamped and rammed in the usual way by hand. When rolled over a support beneath is brought up by a hand lever, the flask is unclamped and the pattern rapped by turning a hand wheel on the trunnion shaft. At the same time the pattern is drawn by lowering the flask. A few of these machines can still be found in use, but the rapping mechanism is not durable, the machine is rather limited in its scope and other types have displaced it for some time.

FIG. 6.



The French machine of Bonvillan & Ronceray is a modification of this type, in which the outer trunnion is omitted and power is added for squeezing the mold and drawing the pattern. This will be remembered as having been exhibited at the Foundry Convention held in Philadelphia in 1907. It has a number of attractive features and is said to be very successful in France, where hydraulic power is more popular than it is here, but the machine has not been so successful on this side of the Atlantic, and it is doubtful that water can compete with air as a working fluid for foundry use.

The advantage of rolling over to draw a pattern is well known and in some cases it is an absolute necessity. This has led to the development of a large number of roll-over machines, nearly all of which drop the mold away from the pattern after the manner of Teetor. The one exception is shown in Fig. 7, and this lifts the pattern from the mold in what is generally admitted to be the logical way. Logical because the pattern is generally lighter than the mold and consequently preferably the part to be manipulated. The machine illustrated is shown as fitted with a grate bar pattern having 140 deep pockets, into which the sand is thrown by hand or settled by jarring the swing frame against its stops before ramming in the usual way by hand. Throwing the sand by hand is preferred, because the jarring process is not uniform and naturally varies with the distance of different parts of the pattern from the turning centre.

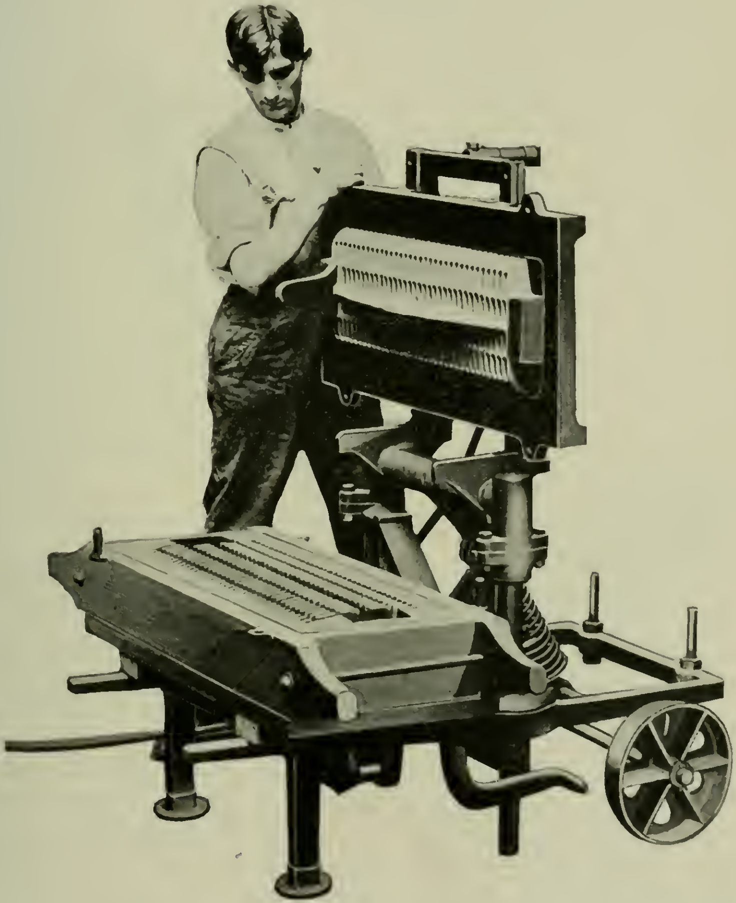
The flask used in this case is 14 inches by 37 inches by 5 inches deep and the time required for a complete cycle of operations was 5.81 min. The cope for this grate bar is almost flat and requires no machine. It could be made by a helper who would have time enough to spare to assist in rolling over, and probably eight to ten molds an hour could be made by experienced men.

In this machine, which takes a flask 24 inches wide and has 7-inch pattern draft, the swing frame and sliding head are counterbalanced by helical springs. These can be adjusted to the weights to be carried and the pattern is drawn by a hand lever at one side.

Since the weight that can be conveniently rolled over by hand is limited to three or four hundred pounds heavier molds naturally require power, and in Fig. 8 we have a machine which rolls over and draws the pattern by means of a cylinder and plunger, using compressed air on hydraulic oil or water to effect the movements.

The illustration shows the pattern drawn and rolling back into position for another flask. In these machines a vibrator is attached to the swing frame and this materially assists in making a perfect draw, the main object of these roll-over machines. They are designed to save pattern drawing and finishing time,

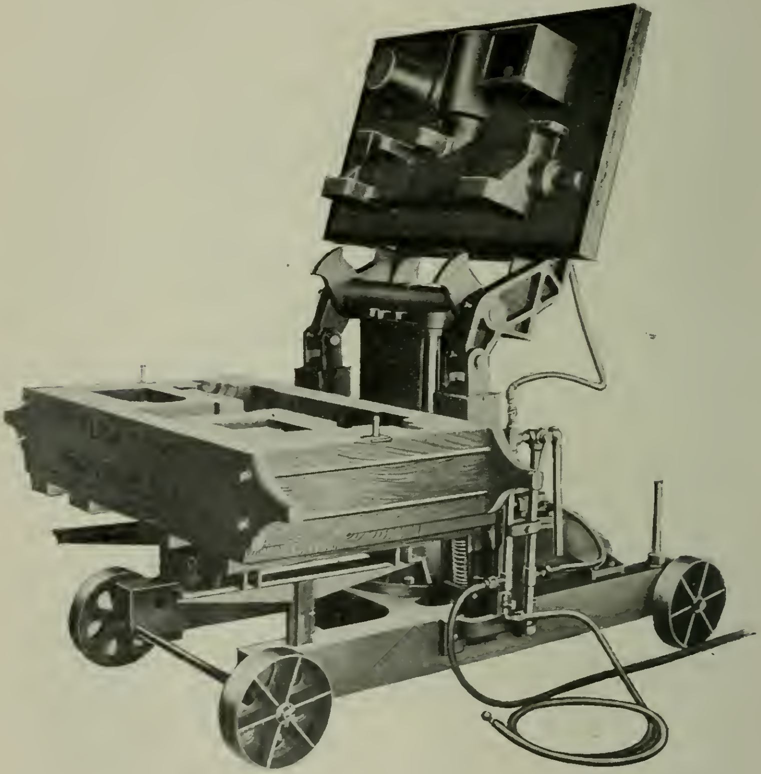
FIG. 7.



and where patterns are of such a character that the margin for this saving is small the time study will show it and possibly suggest a jarring machine instead. But molding machines do much more than save time in molding and are often worth all they cost in the saving of patterns, the saving in metal and the saving in machine work by reason of the greater uniformity and closer finish of the castings produced.

An important feature of these machines is the levelling cradle, of which a number of types have been developed to set the flask with reference to the pattern board regardless of irregularities in the bottom board upon which it rests.

FIG. 8.



Such machines may be fitted with long patterns overhanging the swing frame for a considerable distance at each end. This possibility indicates the scope of the machine and the advantage of rolling over about an axis parallel to the length of the flask instead of about a normal axis as is done on machines of the French type.

Time study on large work may show that a material saving is effected in finishing, in ramming or in both, and where ramming time is the principal item a jarring machine is the equipment most needed to reduce costs. There are quite a number of jarring machines on the market, all of them covered by the original claim of Hainsworth in his patent of 1869, which is so refreshing for its simplicity and breadth that it is worth quoting:

"The packing of sand, for a mold, in a flask, by raising the same, together with the pattern, and letting them all drop upon a hard bed, substantially as shown and described."

There were no permutations and combinations of elements making an extended series of claims calculated to exhaust the patience of the reader. All he wanted was the whole field and he secured it in a single claim, but it is not certain that the packing of sand in this way was altogether original with Hainsworth, and there is ample ground to suspect that groceries of all kinds have been packed in paper bags by the same jolting process before the memory of man runs otherwise, and some of these (dried currants, for instance) there is reason to believe have always contained a liberal admixture of sand. The packing of sand by jarring is therefore in all probability as old as the hills, but since the broad claim of Hainsworth no longer troubles us we must look among later improvements within the field that he covered for the development of the art. This patent seems to have attracted very little attention when it appeared and no further inventions along this line are on record until 1878, when Jarvis Adams gave some impetus to the art and later followed it by a number of patents. The Adams machines were, however, rather crude and very little progress in the art was really made until compressed air came into general use as a medium for the transmission of power.

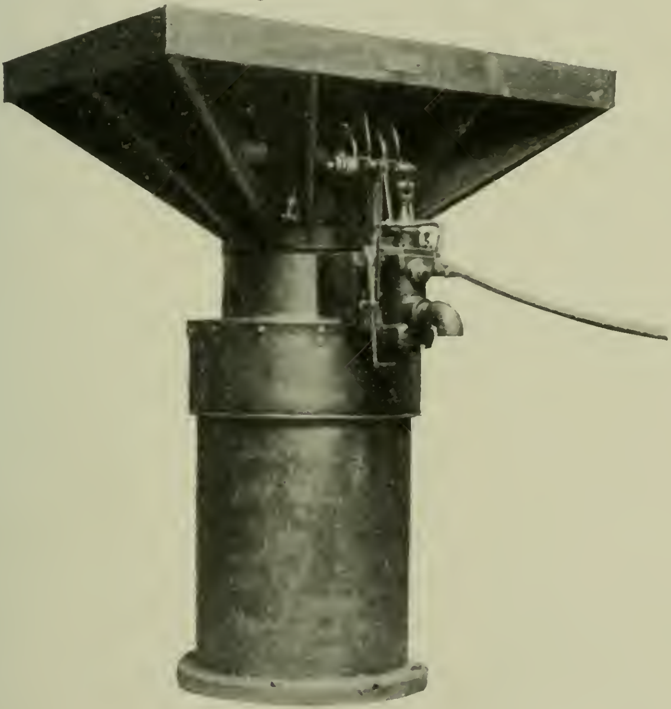
At the present time nearly all jarring machine builders contemplate the use of compressed air, whereas originally, and until about the beginning of the present century, they were operated mainly by hand or by cams on a power shaft. The development of the jarring machine is an interesting study, but no attempt will be made to follow it through all its ramifications; a few examples only representing the last ten years will be considered. In the machine first built the jarring table was struck underneath by a heavy plunger actuated by compressed air. The blow raised the table a short distance from its support, upon which it fell back, striking a second blow. Some of these machines are still in use, but it cannot be said that they are very efficient or successful, and they were superseded five or six years ago by the Tabor jarring machine now in common use.

This is a plain machine with the jarring cylinder formed in the table mounted upon an upstanding plunger. By this construction the table is given enormous strength and stiffness and the central blow of impact is distributed equally in all directions. The plunger is part of a heavy piece of cast iron forming the anvil, which in turn rests upon a large mass of concrete. Originally the main valve was operated directly by tappets attached to the table adjustable for any desired length of stroke, and later it was modified to operate through the medium of a pilot valve. To avoid unnecessary intensity in the blow struck by the table upon its anvil a few layers of leather or other non-resilient material are introduced as a cushion. These reduce the wear and tear and noise, without having any material effect upon the action of the machine on sand. The plunger base rests upon concrete to form an anvil.

As to the mass of concrete, it may be said from the operating stand-point the more the better, but this must be limited, of course, with regard to the cost and the natural bed beneath. In a general way, about two cubic feet of concrete for every square inch of area in the jarring cylinder is recommended, but if there is a rock bottom beneath the use of very little concrete is advisable, or just enough to level up under the cast-iron plunger base. Some builders recommend more concrete than this, some less, and in addition to the concrete a heavy wooden cribwork is frequently put in beneath to prevent the transmission of the shock of impact into the ground. This is in accordance with the usual practice under steam-hammer anvils, and it may have some beneficial effect but it does not eliminate the whole trouble and the wooden crib is scarcely worth its additional cost. It is not generally safe to set up finished molds with hanging sand in the neighborhood of a jarring machine of this type and in some foundries the jarring machine has been put out of service for days or weeks pending the completion of large floor work. In fact, the damaging effect of large jarring machines is too well known to need confirmation, and to reduce this to a minimum the drop of the table has been decreased while the foundation has been increased.

But there is a limit to the relief afforded by reducing the drop, because upon this the ramming effect primarily depends. The shorter the stroke the less the ultimate density attained and the less the efficiency of the machine. This can be demonstrated in a practical way by ramming up a deep mold on short strokes until the sand ceases to pack any further. Increasing the length of stroke very considerably alters the effect of the next blow. The sand will pack further immediately and the conclusion in favor of the long stroke as more efficient in packing sand is inevitable.

FIG. 9.



With the object of eliminating ground shock and yet retaining the use of any stroke desired the Shockless jarring machine, Fig. 9, has been designed. It requires no foundation other than a base to sustain the static load upon it, and it is more efficient in operation than a plain machine mounted on a wooden crib whose anvil weighs twice as much. The principle upon which it operates will be understood from the sectional elevation shown in Fig. 10. The plunger base forming the anvil is mounted for convenience in an anvil cylinder and rests upon a number of long compression springs. When air is admitted to the jarring cylinder the entire weight of the anvil, table, and load is carried upon these springs and they are therefore compressed and in readiness to expand when the air is exhausted and the table falls. At the beginning of this movement the loaded table is impelled downward by the same force that moves the anvil upward, and although some of the force of the springs is exhausted as the anvil rises the loaded table and the anvil acquire substantially equal momenta which neutralize each other when impact takes place. To compensate in a measure for the loss of spring pressure as the anvil rises, the exhaust from the jarring cylinder may be carried into the anvil cylinder before being discharged. This is accomplished by a combination valve, consisting of a large main valve of the steam-hammer type in connection with a small pop valve such as is used on small power squeezers and split-pattern machines. These valves are attached to the anvil or plunger base and the pop valve is opened and closed by tappets on the jarring table. When the table drops the pop valve opens, admitting pressure beneath the main valve, which rises and puts the jarring cylinder in communication with the air supply, at the same time opening the anvil cylinder to exhaust. When the limit of stroke is reached the pilot valve opens to exhaust and the main valve drops to the position shown. The air from the jarring cylinder rushes into the anvil cylinder, expanding to much lower pressure, which is nevertheless very effective in the large anvil cylinder and causes the loaded table and anvil to collide with greater force and effect upon the sand. The supply of air to these valves is controlled by an air cock at the operating stand and the table runs automatically as long as the air is turned on. At the same time the stroke of the table is controlled by another lever adjustable, if desired, while the machine is running. The purpose of the pilot valve is to provide a controlling means, easily manipulated, that will give the delayed action required by the main valve. This always presents full openings during the

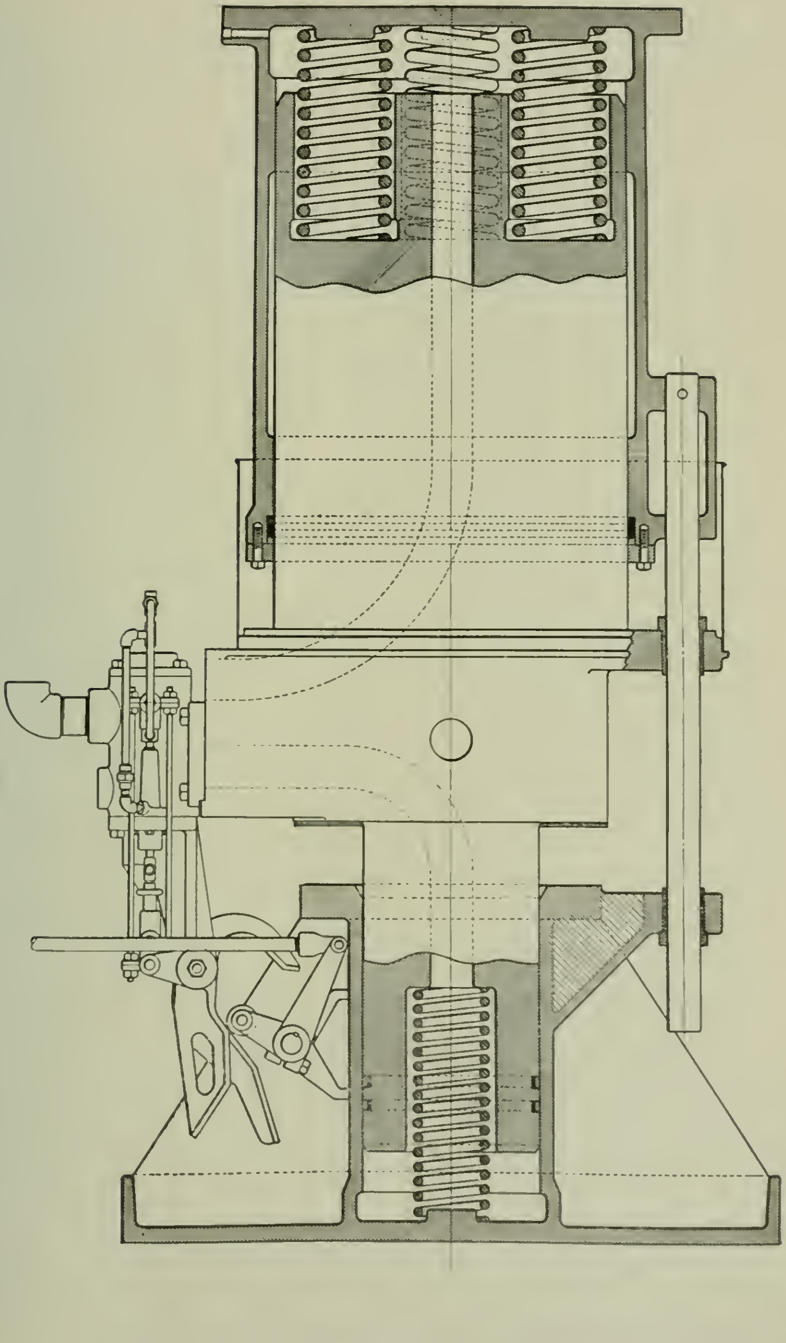


Fig. 10.

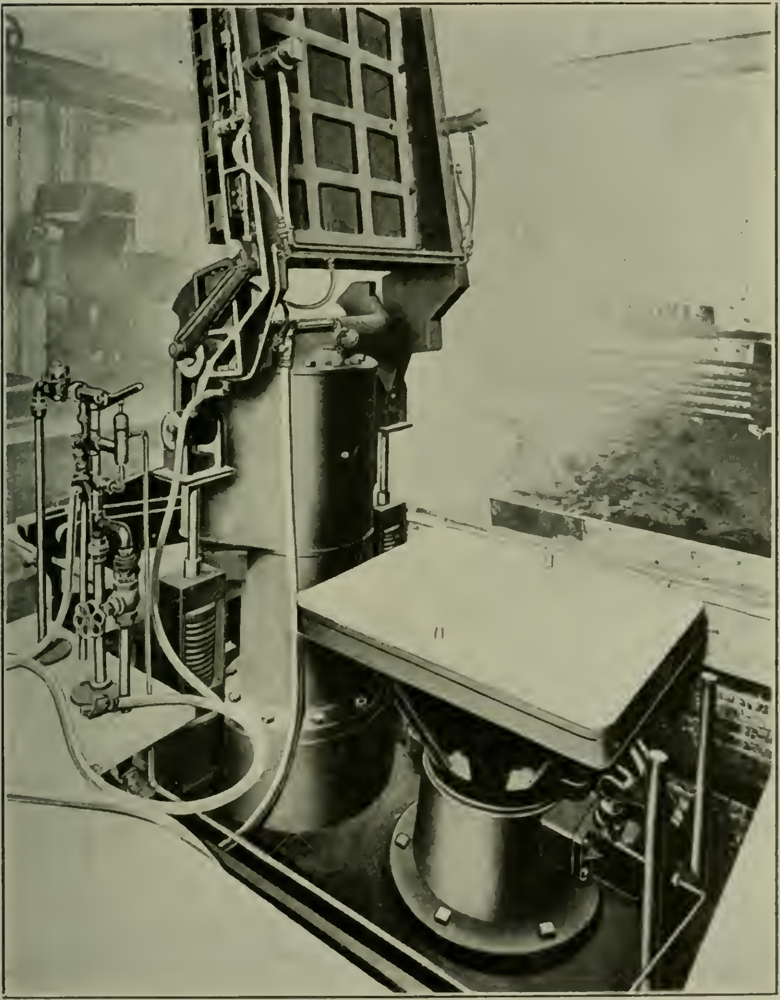
table movement up or down, and the ample lap on the ports gives time for expansion in the jarring cylinder under light or medium loads after the air supply has been cut off. Of course, under full load, or thereabout, there can be no appreciable expansion in the jarring cylinder.

Fig. 9 is taken from a photograph of a 13-inch shockless machine with 4-foot by 6-foot table. A machine of this type will ram any mold, large or small, in a minute or less time, and the saving to be effected by its use on large work is practically the whole of the ramming time by hand. It will not ram small work, such as that on which time study was first given, as quickly as a squeezer or split-pattern machine, and such a jarring machine for half molds weighing less than 1000 pounds is not often recommended, but for large deep work particularly it is by far the best machine for packing sand. It is not, however, every pattern that can be rammed in this way, and care must always be taken to avoid projections on the pattern which interfere with the proper flow of sand. This sometimes necessitates the use of a core not required for hand ramming, but the patterns when mounted for jarring require fewer repairs and the cost of adaptation to the jarring process is soon recovered.

In regard to efficiency, nothing, of course, can be better than an anvil bedded on rock and therefore of practically infinite weight, but even a rock bottom does not prevent the transmission of ground waves, and when a wooden crib is used to cushion the blow the anvil yields to the impact and softens the effect. The advantage of the uprising anvil will therefore be demonstrated and its action illustrated by reference to two cars on a horizontal track. Let these cars be of equal mass or weight and let them be separated a given distance. Now block the wheels of one car and draw the other to it by a uniform force. Assuming the impact to be inelastic the two cars will move on together at half the velocity acquired by the moving car at the time of impact. The shock of collision is the same on both cars, one gains what the other loses, one-half of the velocity of impact, and the square of that change in velocity represents the ramming effect. If the stationary car had been of infinite mass the moving car would have lost all of its velocity and suffered four times the ramming effect.

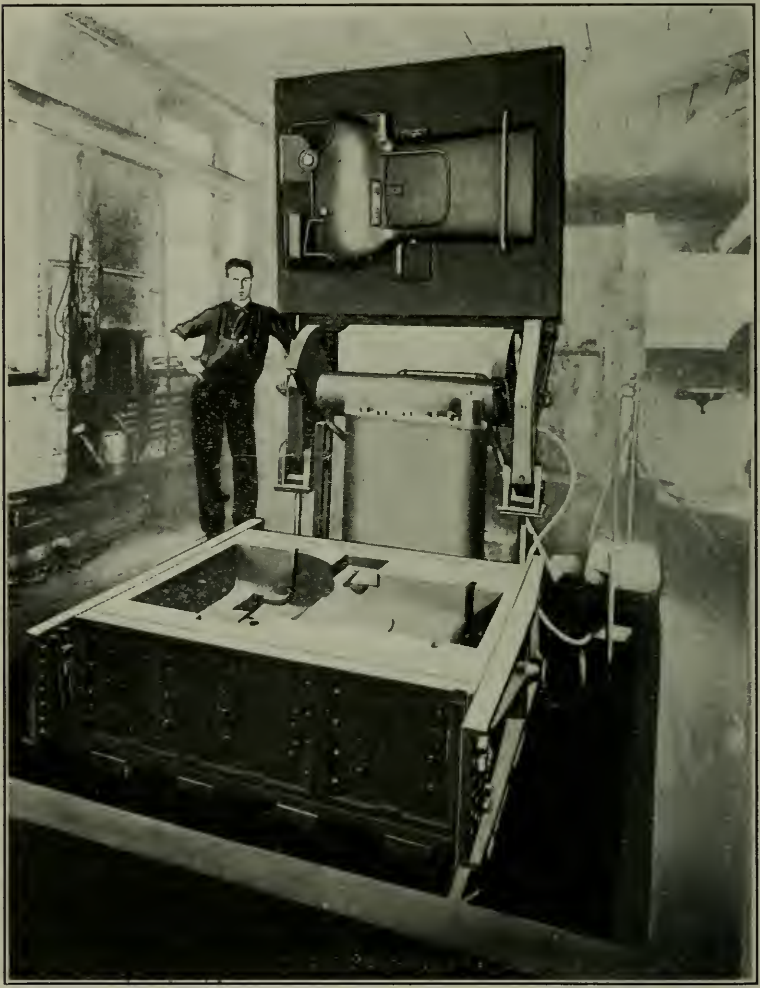
Or, we may say, to invert the comparison, when one car strikes another of the same weight the ramming effect is one-quarter of what it would be if the car ran into a stone wall, or encountered a mass so much superior as to have substantially the effect of infinite mass in checking its velocity. Now, if both cars are free to move and are drawn together by the same force as in the first instance, the same amount of kinetic energy will

FIG. 11.



be developed, but it will be divided between the two cars and totally absorbed by inelastic impact, each car sustaining one-half the shock instead of one-quarter. Therefore, when both cars move together the shock of impact is twice as great as when one car waits to receive a blow from the other one. Furthermore, the highest efficiency, or the greatest shock, is realized

FIG. 12.



between any given pair of cars for any given amount of work done when both cars are actuated by the same force and acquire equal momenta in equal times. This is true for cars of unequal weight as well as for the cars of equal weight just considered, and it can be shown when one car is made heavier than the other to act as an anvil that when both cars are free to move the shock on the lighter car is greater than it would be against a car of double the weight standing to receive the blow. It is not claimed that the shockless jarring machine is always twice as efficient as a plain machine having the same weight of anvil mounted on a wooden crib, although it is sometimes more than twice as efficient. It is simply maintained that the shockless jarring machine is more efficient than a plain machine having an anvil twice as heavy mounted on a wooden crib. But the efficiency of a jarring machine does not depend altogether upon the weight of its anvil, solidity of construction contributes something and the length of stroke still more.

Instances could be cited where production has been increased five times by the installation of a jarring machine and still greater gains have been made from machines which combine the jarring and pattern drawing features just described.

Fig. 11 shows such a power roll-over machine in combination with a jarring machine.

Fig. 12 shows a grinder frame mold made on the same machine. This half mold was made by two men in ten minutes and a complete mold, including core setting, could probably be made in half an hour.

Originally two men made two molds a day by hand. With the aid of a jarring machine they made five a day, and it appears from the time taken on a combination machine that twenty a day might be expected.

Although the foregoing is not a complete summary of the art of machine molding and many types of machines have necessarily been omitted, the point to which particular attention may be called is the harvest awaiting the introduction of scientific management in the foundry and its bearing upon the proper selection and use of molding machines.

Arc Light Electrodes. (*The British Thomson-Houston Co., Ltd., Eng. Pat.* 13,518, June 3, 1910.)—The addition of a small proportion of chromium carbide is stated to increase the life of electrodes composed chiefly of titanium carbide. For example, an electrode may consist of an iron tube filled with a mixture of 4.5 per cent. chromium carbide and 95.5 per cent. of titanium carbide mixture, i. e., titanium carbide 99, sodium fluoride 1 per cent., or titanium carbide 96, sulphur 3, and sodium fluoride 1 per cent.

Effect of Ammonia on Nickel-plating Solutions. Anon. (*Brass World,* vii, 137.)—The presence of ammonia in nickel solution should always be avoided, for it makes the nickel deposit dark in color resembling iron, hard and brittle and lacking the tenacity and toughness of that formed in a neutral or slightly acid solution, and apt to peel. If a large amount of ammonia is present the deposit frequently flakes off in the solution, particularly if a high current density is employed.

Origin of the Thermal Waters in the Yellowstone National Park. Arnold Hague. (*Bull. Geol. Soc. Am.,* xxii, 103.)—The waters of these hot springs and geysers are characterized by frequent variations of temperature and chemical composition, lack of uniformity in mode of occurrence, and shifting of points of discharge. They are essentially meteoric waters that have penetrated downward sufficiently deep to become heated, and are forced back by ascending currents. These thermal waters hold mineral matter in solution, derived from the rocks through which they pass. They may be classified as (1) Waters carrying calcium carbonate in solution; (2) siliceous alkaline waters rich in dissolved silicic acid; (3) calcium siliceous waters, having properties of the two preceding classes; (4) siliceous acid waters usually holding free acid in solution.

Rules for the Prevention of Industrial Accidents. Anon. (*Amer. Mach.,* xxxiv, 1084.)—It is interesting to note the following rules issued by the Allgemeine Electricitats Gesellschaft, Berlin, for the guidance of employees using milling machines and circular saws. 1. All fast-running mills and saws must be surrounded with protecting caps. 2. Special care is to be taken that the stresses on saws and mills are exactly central, or in the plane of the cutter. 3. Damaged or sprung cutters are to be replaced immediately. 4. Small pieces to be cut must be fastened in holders and jigs; the cutting of small pieces held in the hands is forbidden under all conditions. 5. The chips thrown off are to be removed by sheet metal dippers or similar apparatus. 6. The wiping away of chips in front of the mill or saw is only to be undertaken with brooms or by brushes such as are supplied for this purpose.

THE USE OF PREPAYMENT ELECTRIC METERS.*

BY

F. G. VAUGHEN,

General Electric Company.

There is an old saying that "history repeats itself," and although this may not be literally true I think we will all agree that it is necessary to study the past in order to obtain a clear vision of the future. This is true whether we are considering the future of a nation, a man, or a meter; we must look into the past to determine what the future has in store.

The system of supplying various commodities automatically on the deposit of a coin is by no means a modern one, but may be traced to a period anterior to the Christian era. One author states that its invention may be attributed to Hero of Alexandria, a Greek mathematician and physicist, who is supposed to have lived in the first or second century B.C., and in whose "Pneumatics" is described a sacrificial vessel containing holy water which flowed only when money was introduced.

This vessel was placed near the entrance of some of the old Egyptian temples to enable the worshipper as he entered to sprinkle himself with holy water. Its operation was as follows:

When the coin was dropped through a slot it fell on one end of a horizontal beam which, on being depressed, opened a valve suspended from a chain at the other end and the lustral water commenced to flow through a pipe. When the beam had been depressed to a certain angle the coin fell off and the valve, which was counterweighted, again descended and closed the outlet so that the discharge ceased.

The mechanism of this ancient vessel was very similar to a modern automatic machine patented by Mr. Lewis G. Noble, of Boston, Mass., in 1889, which will for a penny dole out a small quantity of liquid perfumery.

It is rumored that even centuries before "Hero" the prepayment system was introduced by priests in the eastern temples to

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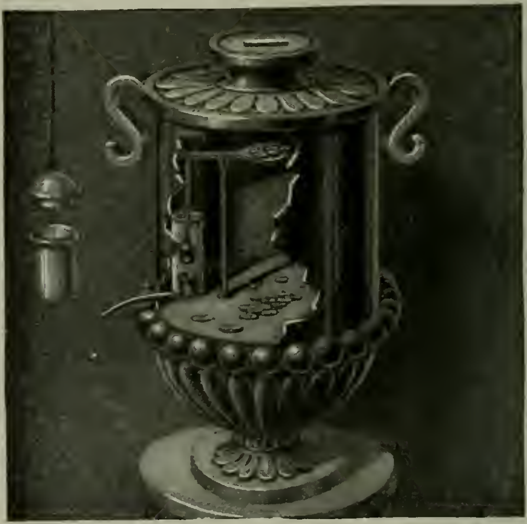
* Presented at the meeting of the Electrical Section, held Thursday, February 2, 1911.

bring tears to the eyes of their gods. This was accomplished in the following ingenious manner: When the worshipper placed his offering on some portion of the image intended for its reception the weight of the offering acting on a lever operated a valve in one of the cellars of the temple. This cellar contained an apparatus filled with hot water, and the action of the valve caused steam to ascend through bamboo tubes to the eyes of the image, where it condensed and became transformed into tears. The object of this, no doubt, was to impress the devotee and probably induce him to increase his contribution to the temple.

FIG. 1.

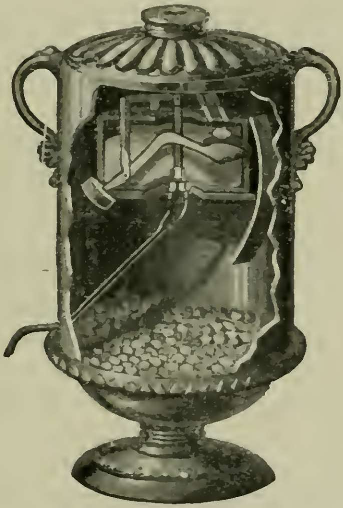


The first prepayment meter. (Date about 200 B.C.)

Truly, as King Solomon has said, "There is nothing new under the sun."

Coming down to modern times, we have only to look around us to see the variety of purposes to which the penny-in-the-slot idea has been applied and the immense popularity of this system for selling commodities. Instance the supply of sweetmeats, cigarettes, cigars, matches, postage stamps, post cards, writing paper, applications in restaurants and cafés where anything from a sandwich to a cocktail may be obtained by dropping a coin in a slot and pushing a lever. Then there are the endless number of gambling machines which may be found in cigar stores, saloons, and hotels, the thousand and one applications in places of amusement, automatic machines for operating phonographs, motion pictures, etc.; photographic apparatus which takes your picture for a nickel and scales which will give your correct weight for a penny. We no longer have to worry even about our future, for "Madam Fortune Teller" will reveal this to us if we but drop a coin in the slot. This same penny-in-the-slot idea is adopted in modern trolley cars where prepayment is made as you enter.

FIG. 2.



Automatic machine patented by Lewis G. Noble, of Boston, Mass. (Date, 1889.)

Indeed, we may exclaim with the poet:

> "An age when all our daily wants,
> Whether they be few or many,
> Will be sufficiently supplied
> By merely dropping in a penny."

A glance at the history of the gas business will show that these undertakings found a field for the prepayment gas meter and obtained great profits from its use.

As previously stated, the slot arrangement was originally used for supplying liquid from a sacred vessel. It was not applied to supplying light until 1887, when the first recorded application for this purpose was made by John Stewart Wallace, an Englishman. In the following year at a southern district association meeting held in England a Mr. W. E. Price, of Hampton Court, read a paper entitled, "Some Hindrances to the Sale of Gas." In this paper the deposit system was severely handled and the remedy shown, Mr. Price exhibiting his early prepayment meter effort. "We have no reason to suppose," says Mr. Price, "that the artisan has any hereditary love for the tallow dip or the paraffin lamp," and provided that gas is supplied on the "pay-as-you-go" plan he predicts an enormous increase in business.

These first meters were complicated pieces of mechanism, and although quite a few were sold, they were, for the most part, ordered in single lots to satisfy the curiosity of the purchasers in seeing to what lengths mechanical adaptations of the penny-in-the-slot principle could be carried. The prevailing opinion was that the meters would never be of any practical use.

Later a number of stop meters were introduced, *i.e.*, meters which could be set to shut off when a certain amount of gas had been used. This was a prepayment meter in a sense, inasmuch as the gas always had to be paid for before consumption. On the other hand it had the disadvantage that the customer could not buy at any time, but only once a week or month. This system was not applicable to the working classes, as they could not be persuaded to buy a week's or a month's supply of gas in advance. Several of the more enterprising gas undertakings in England realized in a measure the enormous increase in their business which would result if the use of gas could be extended to the dwellings of the working classes. As these classes would not stand for the monthly bill or the deposit required when selling gas with an ordinary meter, it became evident that they must be reached through the agency of the prepayment meter.

About 1893 two very large gas undertakings, the Liverpool United Gas Company in the north, and the South Metropolitan Gas Company in the south of England bought a number of these meters and started a campaign to increase their business. Mr. George Livsey, in speaking to the shareholders of the South

Metropolitan Gas Company in 1895, shows how in eighty years the company had obtained only 80,000 ordinary customers; but that in two years the number of automatic consumers reached 20,000. In 1898 this figure had increased to 72,288.

The increase in the business of most other companies that introduced these meters was equally as great. One writer in 1895 says, " The remarkable figures of the Gas Light and Coke Company show that wherever the public can be supplied with all they want to properly use gas for both lighting and cooking upon inducive terms, even at a good round price, they will take it. They object to rentals and deposits, but willingly pay for all supplied in the price of gas."

Every one was astonished at the way the orders poured in. Gas fitters were at a premium, while manufacturers were unable to fill the orders. The rush commenced in 1894, and by 1896 the facilities of manufacture had been increased and the boom, which had reached its height at this time, steadied down to a fairly even but extremely copious demand.

The early meters made in 1892-3 gave quite a little trouble, arising in most cases from the almost clockwork delicacy of the working parts. As the business grew, however, improvements were made; the gas undertakings also became familiar with the devices and knew better how to overcome difficulties; and so the problems worked themselves out.

The enormous popularity of the penny-in-the-slot meter in England was due in part to the fact that the gas undertakings installed fixtures and gas cookers free of charge. At first a slight increase in the charge for gas was made, but this was abandoned later and still the companies made a good profit. The prime reason, however, for the success was the application of the " pay-as-you-go " principle to the sale of this commodity.

An aggressive campaign was issued and the people were shown the benefits to be derived from the use of gas. The tallow dip and the paraffin lamp were thrown aside by the laboring classes and the " pay-as-you-go " system of selling gas was welcomed.

It is estimated that there are to-day over 20,000 prepayment gas meters in use in the United States alone. It is not the practice of gas companies in this country to furnish stoves and fixtures free of charge. In England, where labor is not nearly as well paid as in this country and where a large proportion of the population live from hand to mouth, so to speak, the use of the prepayment gas meter is more general. For instance, in London, where the poorer clases abound, there are 645,000 prepayment and only 384,000 ordinary gas meters.

I do not wish to infer that the gas companies prefer to handle the prepayment meter, for they undoubtedly do not; but they use this meter to cover a field which would otherwise be left undeveloped.

Since the prepayment scheme has been successfully applied to the marketing of the thousand and one commodities in daily use and has been found profitable in increasing the consumption of gas, why should it not be more extensively applied to the sale of electricity? In other words, is there any inherent reason why the prepayment electric meter should not play as important a part in the vending of electricity as does the prepayment gas meter in the vending of gas?

The application of the prepayment method to the sale of electricity is more recent and much less general than with gas. The prepayment gas meter was developed in England over a quarter of a century ago and has since become prominent in this country and abroad. I have understood that the adoption of the prepayment electric meter has been far more general in Europe than in this country and has met with success, particularly with supply companies of municipal ownership. While our experience has been more or less limited, I feel that it has been such that there is no diversity of opinion as to the numerous advantages of a reliable prepayment electric meter, and that it would be of material assistance in the sale of electricity.

That this meter has not as yet become very popular with central station managers there can be no denying. This, I think, has been due chiefly to two causes:

First, on account of the inherent complications of the device, which have made it difficult to build a satisfactory meter; and

Second, on account of the higher initial cost and increased expense of upkeep (*i.e.*, so far as the cost of testing and repairs is concerned) over that of the standard watthour meter.

These features have caused central station managers to hesitate about introducing these devices for fear that they would not be a profitable investment.

It is true that many of the prepayment devices which have formerly been placed on the market have been unnecessarily complicated and costly. In justice to the manufacturers, however, it should be realized that the problem of constructing a successful prepayment electric meter has been exceptionally difficult. The gas meter is quite crude in comparison. In constructing the electric prepayment meter we have an electric arc to break in addition to the usual problems encountered in building automatic coin devices. This must be done in such a manner as to prevent pitting or otherwise injuring the switch contacts, since the switch is a vital part of the mechanism and must be absolutely dependable in its action.

Improvements have, however, constantly been made and it is now possible to obtain reliable prepayment meters for a moderate price.

There are two general classes of customers with whom every central station manager is very familiar: those of questionable credit and the delinquents. These classes are closely related and it is sometimes difficult to segregate them. Under the first would come the occupants of certain apartment houses—transient customers, if you please—who are here to-day and gone to-morrow: foreign districts in large cities where the Italians, Chinese, etc., abound. There might also be included in this class of questionable credit saloon-keepers, proprietors of gambling houses and other resorts needless to define. In fact, such customers are numerous in communities having a floating population such as large cities, manufacturing towns, and summer resorts. All or much of this business may be desirable if the question of credit can be taken care of. A prepayment meter for such installations insures payment in advance. It may also, in the case of the transient customer, save the expense of frequently removing and replacing the meter as well as an extra trip of the meter reader inspector.

The class of delinquent customers can readily be obtained from a careful study of the central station books. There is without doubt a small percentage of customers who are habitually behind in their payments. One or more collectors, depending on the size of the station, are often necessary to collect the bills of these customers.

The services of these collectors may be likened to the police department in a large city, which has to be maintained at a large expense to protect the whole body politic from the depredations of the very few who compose the criminal element of the community. So the collectors are paid to keep after a small number of customers who are ever behind in their payments.

There are some who even avoid the collectors or refuse to pay them, in which case the company writes the customer and threatens to cut off the supply unless the bill is paid; and later, perhaps, is obliged to actually disconnect the circuit. Left in darkness, the customer generally pays his bill and the meter must again be connected. All of this means extra expense for the central station.

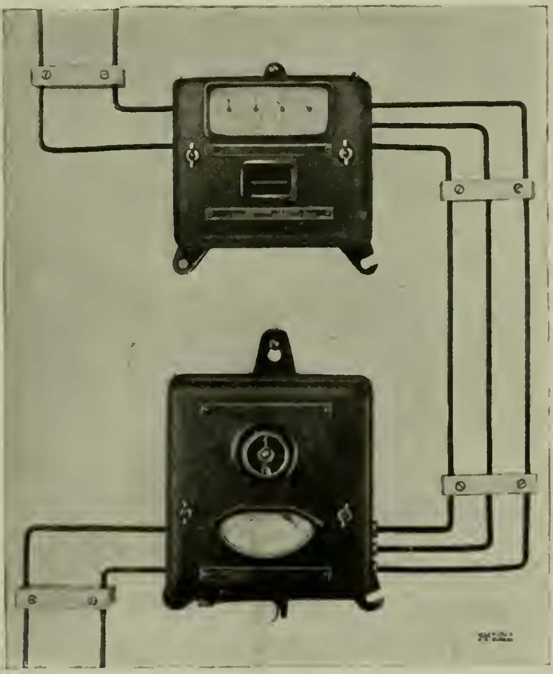
Now if these delinquents could be furnished with prepayment meters the company would not only save all of this expense incident to collecting but would free the customer himself from the annoyance of constantly being prodded. A discontented customer is always a poor advertisement; and if the friction between the central station and the delinquent customer, together with the cost of collecting, can both be eliminated by the use of the prepayment meter, it should pay a good profit on the investment.

Besides the matter of collecting, it should also be remembered that the use of the prepayment meter will reduce the expenses of the accounting department by eliminating the cost of billing, and will also cut out the items of postage and stationery.

Another class of customers who cause the central station considerable trouble and expense may be termed, for want of a better name, " The Doubting Thomases." They are sure that their meter is reading too fast and that they are being robbed. To pacify such customers it is necessary to spend much time and money in making frequent explanations of the correctness of bills. Often the customer insists on the meter being recalibrated. He lacks confidence in the device and must be shown that it is accurate.

Now in the majority of such cases the meter is practically correct. The customer has failed to realize that the days are growing shorter; that perhaps he has been entertaining more than usual; or has recently purchased an electric flatiron, fan motor, or other auxiliary device which is consuming more power. Some companies instal a prepayment meter on the premises of such a customer, connecting this in series with the regular watthour meter. In this way the customer can check his meter and at the same time often finds out for himself where the extra power is being used. If, for instance, he has to make an extra deposit he remembers that he forgot to turn out the cellar lights the day before, or some other cause for this increased consumption will likely occur to him, whereas if he didn't pay his bill but once a month he would not remember the little instances which make it abnormally large. In a very short time the prepayment meter may be removed from such a residence and it generally leaves a contented customer where it found a chronic faultfinder.

FIG. 3.



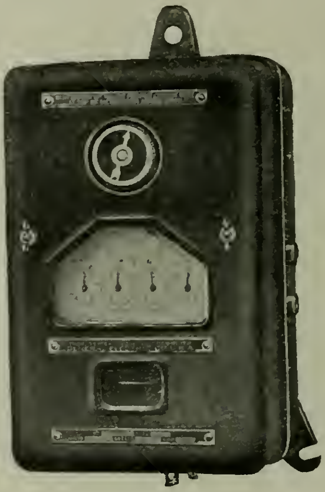
Standard Watthour meter and prepayment meter in series.

Again, there are a large number of people who belong to the so-called "pay-as-you-go" class who think nothing of spending a considerable amount of money in small instalments, but who look on the monthly electric light bill as a burden and will not use electricity for this reason.

In these days when the central station is reaching out on all sides for new business and resorting to all kinds of schemes in order to make electricity popular, why not try and reach this pay-as-you-go class through the agency of the prepayment meter?

All customers who are mentioned above, and perhaps others familiar to the supply companies, are revenue producers but not in the average profitable, due to expense involved for reasons outlined above; yet the supply companies cannot afford to lose or refuse to do business with them. The prepayment electric meter provides the simplest and most feasible solution of cases herein cited. How simple it would be for the commercial department of the supply company, with the electric prepayment meter at its disposal, to deal with prospective customers, either through solicitation or application, that have no credit standing but whose business looks desirable except for the one reason—poor or doubtful pay—to eliminate the usual routine and say, "We will put you on prepayment basis" and therefore close the business without delay and further expense to the supply company.

FIG. 4.



Prepayment meter.

Of course, each central station must work out this problem to suit its own local conditions.

There is no doubt whatever that the prepayment meter is particularly well adapted for the field specified above and the wide-awake central station manager will find where he can increase his profits by its use.

To meet its field it is evident that the successful prepayment electric meter should be of simple and robust construction, made from good materials and with the best of workmanship, having as few delicate parts as possible. It is the tendency of the designer to-day to follow as nearly as possible mechanical principles, thereby aiming to avoid a complicated mechanism. The fact should not be lost sight of, however, that no automatic device—no matter how simple—can be left to itself year in and year out without any attention whatever and be expected to do its work in an entirely satisfactory manner.

FIG. 5.

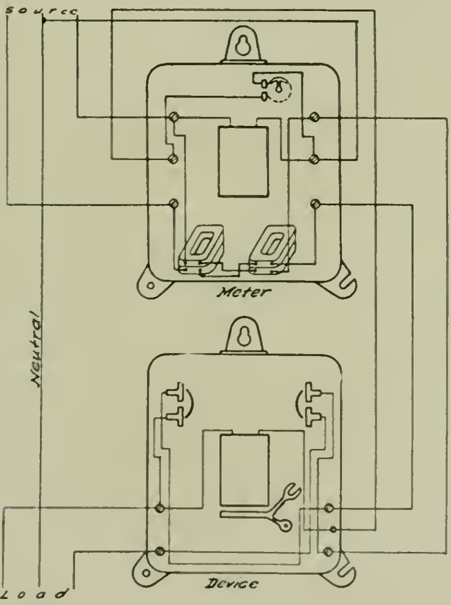


Diagram of connections.

A successful prepayment meter should be reasonable in price, reliable, accurate, and unalterable by anyone not in possession of a key. The actuating force of the device should be foreign to the meter proper. It should be adapted for any commercial rate of charge and should be so constructed that this rate can be easily changed.

It should be designed to operate with a standard coin of wide circulation. Provision should be made so that several coins may be inserted in succession, after which the coin slot would be automatically closed.

It should have a dial to record the total energy which has passed through the meter and a pointer to indicate at all times the number of coins which remain to the customer's credit.

It should have a reliable switch, preferably of the double pole type, for opening both sides of the line.

The General Electric Company has recently placed on the market a new prepayment attachment for use with the Thomson watthour meter which meets the above specifications.

FIG. 6.

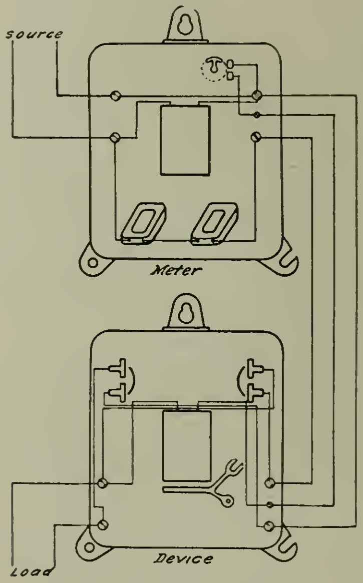


Diagram of connections.

The attachment may be furnished either in combination with the General Electric Type I High Torque Induction or Type C-6 Direct Current watthour meters or as a separate device. The principle of operation is the same in either case, but the connection between the meter is mechanical in the former and electrical in the latter.

The combined attachment, however, is the one most generally used and seems best adapted to meet the majority of service conditions. It has the distinct advantage of being complete in itself, depending on no auxiliary device, occupies a minimum space and requires the least amount of material and labor for installation. The separate attachment is available for use on those installations where it seems advisable to place the device in a more secure or accessible position than the meter itself.

In the case of the Thomson watthour meter with separate prepayment attachments the meter proper is standard with the exception that it has an extra terminal for making connections with the solenoid circuit of the device and a special register with contact brushes for closing this circuit at the proper time and thus operating the prepayment mechanism.

The actuating force which operates the device is a large, flat coil spring enclosed in a barrel or drum to which its outside end is attached. The operating knob winds this main spring by turning the drum. The spring has many turns, and as the operation of the device never equals one whole turn the spring always exerts a practically constant force.

The coin chute and receptacle in the combined device are at the back of the meter, so that when the meter is inspected or repaired the coin box is not interfered with in any way.

The switch is of the double pole, double-break type with leaf contacts and toggle joint. The double pole arrangement permits the meter to be used on both two- and three-wire circuits; while the toggle joint insures a good contact which is undisturbed by any jar, and at the same time prevents any back pressure from being transmitted to the escapement train.

The meter can be furnished for any commercial rate of charge. The rate device consists of a small train of gears, furnished as a separate member, which may be easily removed and replaced by the company in case it desires to change its rate of charge.

The meter is operated by a 25-cent-piece and every precaution has been taken to prevent fraud. A coin larger than a quarter of a dollar cannot be introduced into the receiving slot, while smaller coins will not operate the device.

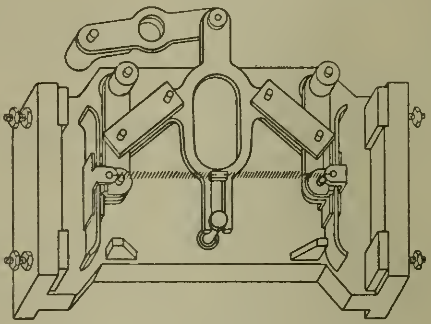
When it is desired to make a deposit the winding knob is turned so that the arrow points upwards. A quarter dollar is then inserted in the slot and the knob turned to the right.

The coin serves as a key to operate the mechanism in the device. If the circuit is open when the coin is inserted the same motion of the knob, which moves the registering mechanism, closes the circuit switch contained in the attachment.

The dial plate of the combined prepayment meter contains, in addition to the standard four-pointer dial, a scale over which a pointer passes indicating the number of coins remaining to the credit of the customer. When the meter has a separate prepayment attachment the dial showing the number of coins standing to the customer's credit is placed on the attachment.

When the first coin is deposited and the knob turned closing the main switch the pointer rests opposite the first division on the scale. If a second coin is deposited before the current purchased with the first coin has been consumed, a second motion of the knob will bring the pointer opposite the second division on the scale.

FIG. 7.



Switch used with prepayment meter.

Twelve coins can be deposited consecutively, after which the slot is automatically closed and further prepayment cannot be made until the value of one or more coins has been consumed. Whenever energy to the value of one coin has been delivered through the meter the escapement is released, mechanically in the combined device and electrically in the separate device, turning the pointer back one division. This process continues until all the energy for which prepayment has been made has been delivered, at which time the circuit switch is opened and no more current can be obtained until more coins have been deposited.

SMALL PUBLIC SERVICE PROPERTIES AND THEIR FUTURE.*

BY

W. S. BARSTOW.

As we have followed the development of public service corporations we have come to realize their every-day influence in large communities where they have become indispensable wheels of industrial progress.

The small communities noting the valuable contribution such corporations offer, set about to at once secure some of these advantages.

The public service corporation of the large community, after passing through the dark days of early development, has practically and satisfactorily solved its problems. Fortunately for itself and the public this development has been in the hands of broad-minded men who, overlooking immediate but ofttimes temporary success, have striven to build up a permanent industry on a firm foundation.

In these days of public clamor against the large corporation or—in newspaper language—the trust, it is interesting to study the subject from the commercial and practical point of view, setting aside for the time being the various theories which exist as theories but not always as facts. In this the engineer, accustomed as he is to deal with facts as well as theories, is well fitted to set aside sensational sentiment and regard the subject in an every-day practical light as to the effect of the large public service corporation existing—if you please, as a monopoly—on the public in general. By "public in general" is meant not only that portion occupying the dense centres of population but also that portion which in scattered communities contributes equally in shaping general progress.

The small towns of some 5000 population question among themselves, without in any way differentiating as to local surroundings, why, if gas, electric lighting and railway properties are such contributors to the upbuilding of a large city, they would not be equally stimulating to smaller communities. The small company is started on misconceived notions as to financial results, without proper investigation of local conditions or conclusive, well-developed plans for future growth. Review carefully the years of study of service, rate questions, engineering problems, etc., that the large corporation has passed through and contrast them with the haphazard manner which characterizes for the most part the birth of the small property. As a general rule the enterprise is hurriedly conceived without any reference to permanent success.

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* Presented at the meeting of the Mechanical and Engineering Section held Thursday, April 6, 1911.

We will not dwell upon the small town electric railway, for its life is generally short and if not, its death is lingering. A recent application before a public service commission of an eastern State prayed that permission be granted to remove and sell two out of the three miles of track so that the company could secure funds to purchase a new car and enlarge the car barn to accommodate the car, setting forth that unless this petition was granted a receiver would operate the property. Numerous citizens appeared at the hearing to protest on the basis that the franchise covered the full three miles, as the town desired to populate this three miles and could not as well do so without the car line. The application was granted and the road is not in a receiver's hands—yet. The history of the particular enterprise is interesting. The venture was promoted by a leading citizen of the town who gathered together sufficient local funds to, as was expected, complete a three-mile railway system. It was submitted to an engineer who reported at once that the enterprise could not succeed owing to the small and scattered population. The citizens replied that their conditions were particularly fitted for its success and forthwith sought another engineer who gave a decision agreeing with that of the first engineer, at the same time adding that the estimate of cost was entirely too low. The road, however, was built by local talent and before purchase of proper rolling stock was completed all available funds were exhausted. The citizens who had contributed were few and wealthy but to save, as they thought, what they had already invested, made the application to reduce the length of the track system, and the balance of the population who never rode but prided themselves upon the town possessing a street car system, protested. The only final salvation of such a small enterprise is the hope that some day in the near future the mile road may become a link of an interurban system.

The birth of the gas or electric property is somewhat similar.

One or two public-spirited citizens, eminently successful in their own manufacturing or mercantile business but utterly oblivious or not even suspecting the difference between selling a commodity and rendering a service, spend a few hours debating the subject, call a general meeting and the public service seed is sown—a seed which, if it is fortunate enough to escape municipal soil, is planted in unprepared ground. The gas or electric light proposition appeals to the quiet citizen as a new thing—a new toy, which at least for a short time will furnish amusement, and at the same time, to his mind, be productive of profit. The leading citizens, forming themselves into a committee, devote their spare time in general investigation. They find the large companies of neighboring cities well financed, well engineered and well operated, giving good, reliable service and in return securing a good and proper income. The last appeals to the small citizen and without further investigation a report is made to the effect that allowing for the wasteful (?) methods of operation which they had observed in large cities the returns should easily amount to 20 per cent. on money invested,—and forthwith the local company is formed. General interest grows—the town paper, heretofore padding its news columns with associated press clippings, at once hails the venture with joy and assumes a public protecting attitude against the proposed gas or electric "trust." Every issue contains advice. A wealthy gentleman of leisure, having made his fortune in mercantile business and having a son employed in a hydro-electric station in the northwest, not financially interested in the local undertaking, deplores the shortsightedness of the promoters who insist upon the adoption of steam power when right beneath their very eyes runs the town brook which contains at least four ripples in the length of a mile and such a lot of water *in the spring*. Another party, having served his time as oiler in a large plant, deplores the adoption of the small unit of one hundred horsepower when looking ahead in keeping with the rapid (?) growth of the town a five thousand "kilewag" unit would be the proper thing. Again, a retired gentleman having a few shares of stock in a small steel company thinks the gas proposition as a pure gas proposition all wrong, for if a coke plant was built the gas would be a costless by-product. After a few more such items of *"advice from one who knows"* the financial heads of the local company hold a meeting and resolve to hire the expert services of the ablest engineer and have him tell them all he knows "for a fee not to exceed one hundred dollars, which if possible should cover the plans of the plant." After vainly seeking outside talent in accordance with the terms of their resolution they appeal to the town electrician, who in the meantime has been busy "reading up," and impressed with his discourse on "frequency, resonance, induction, etc.," engage him at once at fifty dollars (thus saving (?) fifty dollars), and to them their troubles are over. (This is an actual history of a small service property and is typical of the majority.)

And now to follow a company, underfinanced and engineered. I was asked to value a small property which was about to pass into receiver's hands. The local engineer and superintendent met me at the railway station. He was blue; the enthusiasm of starting a new enterprise had vanished as had also the cash capital of the company. He explained sincerely that he had done *his* best. He had started the plant with 133 cycles, had quickly seen his mistake and added some 25 cycle apparatus, had later noted the rapid progress of large Edison plants and had forthwith added a direct current system—this in addition to a series arc direct current and enclosed arc alternating street system. He felt sure he had been progressive and up to date and could not understand the receiver proceedings. "The plant had only been in operation four years and no enterprise could expect to make money at the very start." After becoming better acquainted I found him earnest, willing and honest and an indefatigable worker, completely wrapped up in the undertaking, arriving at the plant at seven every morning and never leaving until nine or ten at night. He would have made an efficient and conscientious subordinate but without a master mind to direct his energies he was helpless and in fact a positive danger to the proper development of an enterprise.

Another property was about to pass into the hands of new owners and a balance sheet was asked for. It was a wonderful balance sheet. The bookkeeper frankly admitted he did not know what had become of the surplus and no accounts, as kept of the company, seemed to dispute his assertion. He stated he had spent many nights trying to secure a balance and had finally done so by adding an item of miscellaneous expenditures. When asked what these covered he stated "you can search me but I am dead sure it will not balance without them." The engineer of this property had been operating the plant with a handbook. He had purchased a new piece of apparatus and after operating it a week telegraphed the maker "Send man at once, instruction book says there are thirteen oil holes, have lost one and cannot find it." And yet there are thousands of such men operating small stations who, implicitly following set rules of operation, are mere machines. When troubles come, as they inevitably do in electric light or gas plants, confusion reigns and poor service results.

As a general rule the independent small plant, which to all outside appearances is prosperous, conducts its operations with no thought of depreciation, an open construction account, and an ability to incur an unlimited floating debt. Under such encouraging (?) conditions dividends are easily earned and declared only to find at a future period that something is wrong somewhere and expert service or a receiver is necessary to continue the enterprise.

The problems of the small corporation are perhaps of secondary importance as affecting the general development of the art, but to the small investor and operator, they are intricate and difficult of solution owing to narrow financial margins. In many cases the fault lies in the conception of the venture.

Generally speaking, no community of five thousand or less, and few of ten thousand population, can independently support a public service enterprise.

The first problem of a small gas or electric company is the making of proper provision for economical financing, not only at the start but afterwards to keep up with the growth of the community it serves. Its original backers soon tire of its continual call for new capital, especially if they have been disappointed in their expectations as to returns. The company endeavors to bond its property but soon tires of the efforts necessary to enlist the attention of the individual investor—individual investor, because in order to enlist the services of the banker and his clients the bond issue must be of considerable size and the enterprise well known. Thus in almost every case the small company turns to its local banks, which, as long as the amount involved is small and the loan properly secured, may aid the undertaking. But this is not permanent financing, for there soon comes a time when the local investor is not desirous of increasing his holdings and the bank can no longer consider so much of such collateral which is not easily and quickly convertible into cash. The inevitable result is necessity for curtailing all construction improvements or extensions and soon strict economy (?) in operation results in poor service and lack of proper provision for depreciation.

The second problem of the small property is the securing of proper engineering and operating services. This is difficult because ofttimes it requires the very best of talent to overcome the many little daily difficulties the correct solution of which is vital to the success of the enterprise, and the finances do not permit of the expense of such talent.

How then is the small property to be cared for and its future safeguarded? Where a number of small communities are within the proper engineering radius of supply, or adjacent to a large property, financial and physical consolidation supplying all from a common source is without doubt the solution of the problem. The securities in this case are of sufficient size to interest the banker, who relieves the company from this financing burden. All engineering and operation is under a common efficient head and its cost being distributed does not impose a burden. The radius of such supply, with advance in the art, is constantly increasing until to-day we see many small communities in the northwest and elsewhere receiving the very best of service over transmission lines several hundred miles in extent and covering territory remote from railway or civilization where electric irrigation or electric mining is opening up a wilderness hitherto almost unknown.

In this locality the proposed Lehigh Valley electrification will cover the territory with transmission lines which form a common source of supply, will aim to efficiently serve the greater part of some 2,500,000 people living in this region. Under these conditions the small communities are bound to thrive as never before, for the citizen with improved means at his disposal and relieved from the petty trials of the local plant can devote all of his best energies to growth of his own business in the development of which he can render his greatest service to his community.

But where physical consolidation is not yet possible, owing to location or other restrictions, what is the future of the small property? Where such is the case financial, engineering and operating consolidation will take the place of financial and physical consolidation. One large corporation (which may be termed if desired, a holding company) by the acquiring of the small properties can consolidate the various securities into one, thus indirectly placing the small properties collectively on the same financial basis as the single large operating company.

At a Convention of the National Electric Light Association held at Atlantic City some few years ago Mr. Frank A. Vanderlip of the City National Bank of New York, gave an address which pointed to the solution of the financial problem of the small property. The substance of his remarks was to the effect that while engineering had undoubtedly solved the operating problems of small properties by a supply from a common source —a difficulty now existed on the financial side. The banker is interested in and could finance propositions where the amount of the securities was large and the properties and their management known. The difficulty existed in the financing of small independent properties which were not financially consolidated, where the amount of the individual securities was small and the management unsettled and unknown. The solution, according to Mr. Vanderlip, was a consolidation of such securities. Thus, if in place of ten small properties of 10,000 population each, having bond issues of say $100,000 each, which small amount would not interest the bankers, there could be one bond issue of $1,000,000, covering a combined population of 100,000, a condition would result which would at once invite outside financial aid. The banker must be conservative and protect his clients and he sees in the small independent property the chance of a single accident imperilling the earnings of the property even to an extent which might affect bond interest.

A holding company owning and consolidating all the bonds of several small properties, at the same time providing for supervision of operation, can increase the factor of safety and can secure for the small property favorable banking consideration and cheaper financing. A small property in Pennsylvania in a town of some 10,000 population has been endeavoring for some time to dispose of an issue of $50,000 first mortgage bonds. The plant is in good condition, the management unusually efficient, the franchise fair to the company and the public and yet efforts have been made time and again with resultant failures to market such bonds at 80 or at a loss of $10,000 to a company where every dollar counts. As a comparison with this we have a smaller company in a community of one-half the size which, under the wing of the holding company, secures 90 for its bonds, simply because these bonds being part of a large consolidated issue and being marketed with additional bonds covering requirements of sister companies, make in the aggregate an issue which is at once attractive and safe, depending as it does upon the average results of several companies.

By centralized supervision of operation the best talent is instantly available and at a cost proportionate to the size and importance of the property. Supplies hitherto purchased from retailers in small quantities can be secured at prices which show considerable reduction and the ever present question of depreciation can receive its proper consideration.

But the question naturally arises, if the solution of the future of the small properties is either in direct consolidation with a large operating company, or in what might be termed indirect consolidation with a large holding company, although in either case the small property may be best taken care of financially and otherwise, what will be the result? In other words what will safeguard the public interest? The theory that competition is in any way a solution is out of the question where franchises and occupation of the same public property are concerned, and where the service to be performed can best be done economically by a single company. The answer to the question brings in *supervision* and *regulation,* and in this connection I quote from a speech recently made at Syracuse, N. Y., by Mr. E. J. Page, who spoke of the relations between railroad men and the Public Service Commission.

"Your predecessors," he said, "and the predecessors of the stockholders of the corporations you operate did not understand the meaning of the term 'Public Service corporation.' They seemed often to think that the service was or should be rendered by the public for the benefit of the corporation to the end that it might pay dividends to its stockholders. The feeling of obligation to the public was too often lacking. That day has happily passed away and most people familiar with the spirit and practice of the managers of the public service corporations have come to realize that the assets of every public service corporation are divided into two classes. The tangible assets represented by capital stock securities held by the people who have furnished the funds and skill necessary for the creation of those assets. On those securities they are entitled to income in the form of interest and dividends. Then there are the intangible assets represented by the franchise furnished by the general public and on this the general public is entitled to income in the way of good, prompt, safe and efficient service at as low a price as is consistent with good financial management of the corporation. The corporation first in any public service field should be protected to the exclusion of all other applications so long as it renders such service as the public is entitled to receive."

And another by Mr. Theo. N. Vail, of the American Telephone & Telegraph Co. President Vail in his report to the stockholders says:

"Public control or regulation of public service corporations by permanent commissions has come, and come to stay.

* * * * * *

"State control or regulation should be of such a character as to encourage the highest possible standards in plant, the utmost extension of facilities, rigid economy in operation, rates that will warrant the highest wages for the best service, and such certainty of return on investment as will induce investors not only to retain their securities but to supply at all times all the capital needed to meet the demands of the public. Such control and regulation can and should stop all abuses of capitalization, of extortion, of overcharges, or of unreasonable division of profits."

The cost of service depends to a very large extent indeed upon the volume of business. In order to reduce the cost to the lowest point all available business must be secured and this results in a monopoly. The Public Service Commission of the Second District of New York states, in the case of the Binghamton Light, Heat & Power Company, "A public service corporation is in its nature an essential monopoly. A monopoly by the very fact of being a monopoly gets all the business there is . . . With a monopoly, if the density of the business gives extravagant profits, it is the duty of the State to cut down the price so that the monopoly obtains only reasonable returns. The evil of monopolies is that uncontrolled they can charge prices which will give excessive and unreasonable profits."

This brings us to the Public Service Commission per se. The greatest argument against the Commission is the uncertainty of its personnel, but is this not also true of the entire structure of government under which we live? There is no question or doubt in the minds of the financier, the engineer, or the thinking public that the Public Service Commission as a regulating commission has come to stay, and already it has shown its value in acting as a safeguard to the company as well as the public. Too many people do not understand the functions of the Commission. It does not, as many suppose, espouse the cause of the people against the corporation, but simply acts as a Court of Justice.

In the brief history of our Eastern commissions, notably those of Massachusetts and the Second District of New York, there are countless cases on record showing clearly the impartiality of their decisions and the resulting benefits to the company and to the public. One example will suffice. A corporation receiving a franchise from the public must secure permission to exercise such franchise from the Commission. If a franchise through politics or otherwise is granted from the same territory or community in which a company is already doing a similar business, and if the company is living up to the requirements of the law as required by the Commission, the corporation securing the second franchise will not be permitted to exercise it. In other words, the Commission creates a monopoly, *but subject to laws which it can enforce.*

Many financiers are fearful that the Commission will so adjust profits that the future preservation of the property will be in danger. This has been shown by the decisions of all commissions to be the reverse. The question of depreciation itself, often lightly dwelt upon by the operator, is counted by the Commission as an element of the cost. The return on the investment has not been limited to the legal rate of interest but to rates *commensurate with the risk of the business.* Recent decisions have been rendered to the point of including surplus in the item of cost, as only in this way fair returns on capital invested can be secured *at all times,* thus preserving the credit of the company in times of depression and so indirectly benefiting the public.

Give us an efficient commission that will devote its efforts to the regulation of the public and the corporation, an honest and reliable management ever desirous of keeping abreast of the times in meeting the ever increasing requirements of the public and we will at once have a stable industry meeting all the expectations of the investor, the operator and the public.

THE COEFFICIENT OF EXPANSION OF TAR.

BY

JOHN MORRIS WEISS,

Barrett Manufacturing Company.

Coal tar and other tars are commercially bought and sold by the gallon, and as temperature plays an important part in liquid volume measurements it is essential to know the effect of changes of temperature on volume. This knowledge is summed up in the coefficient of expansion. Now, coal tar from various sources varies considerably in composition and hence also in its expansion coefficient.

In this paper are presented tests of various kinds of tar, along with their coefficients of expansion as determined in the laboratory.

The method of procedure was simple. The specific gravity of the tar was determined at various temperatures compared to water at the same temperature. A specific gravity bottle of 50 c.c. capacity, whose weight and water content at various temperatures were known, was filled three-quarters full of tar and weighed. Then water was added, adjusted to the temperature desired and weighed.

a = weight of bottle.
b = weight of bottle + water at t°.
c = weight of bottle + tar.
d = weight of bottle + tar + water at t°.

$$\text{Specific gravity}: \ t^\circ/t^\circ = \frac{c - a}{(b - a) - (d - a)} = \frac{c - a}{(b + c) - (a + d)}.$$

From this figure the density, or a direct mass and volume relation, could be readily obtained by multiplying the specific gravity by the density of water at that temperature. This can be seen in the following formulæ:

Let D_t = density of tar at t°.
M = weight of given quantity of tar.
V = volume of that tar.
D_w = density of water at t°.
M_w = weight of an equal volume of water at t°.

The known equation is—

$$\text{Specific gravity}: \ t^\circ/t^\circ = \frac{M}{M_w}$$

Now

$$D_t = \frac{M}{V} \qquad (1)$$

$$V = \frac{M_w}{D_w} \qquad (2)$$

Substitute (2) in (1):

$$D_t = \frac{M}{\frac{M_w}{D_w}} = \frac{M}{M_w} \times D_w = \text{specific gravity of tar at } t^\circ \times \text{density water at } t^\circ.$$

Now in experiment the following figures were determined for a tar

at	a°	D
"	$(a + b)^\circ$	D_1
"	$(a + 2b)^\circ$	D_2

and assuming a constant mass

at	a°	V
"	$(a + b)^\circ$	V_1
"	$(a + 2b)^\circ$	V_2

a° and $(a+2b)^\circ$ were the limits of temperature in which tar are usually measured and it was found that for all practical purposes

$$V_2 - V_1 = V_1 - V$$

or

$$\frac{V_2 - V_1}{b} = \frac{V_1 - V}{b} = \text{constant.}$$

Then if V is taken as unity the constant represents the amount 1 unit volume of tar will expand or contract for 1° change in temperature.

To illustrate the above by a practical example:—If on a tar we found

60°F. density = 1.200
100°F. " = 1.185
140°F. " = 1.170

then

60°F.	1	volume
100°F.	1,01266	"
140°F.	1,02564	"

$$V_2 - V_1 = .01298 \quad C = .000324$$
$$V_1 - V = .01266 \quad C = .000317$$

On writing the fifth significant figure 2 we have .00032 as the coefficient to be used in that particular tar. In practice the problem involved is to reduce a volume of tar taken at a higher temperature to 60° F.

So if

v = observed volume
t = temperature in °F.
c = coefficient of expansion

$$V_{60} = V - V\,(t - 60)\,C$$

In the accompanying table are shown a number of dry tars thus tested, giving free carbon, specific gravity, and coefficient of expansion.

To summarize:

1. The coefficient of expansion of tar is defined as the amount one unit volume of tar will expand or contract for one degree Fahrenheit.
2. The coefficient is practically constant for any particular tar in ordinary ranges of temperature.
3. The coefficients of expansion of a number of tars are given.

Source of tar	Free carbon, per cent.	Specific gravity at 60° F.	Coefficient of expansion for °F.
Water Gas Tar.........	1.04%	1.073	.0003750
Water Gas Tar.........	1.08%	1.090	.0003550
Gas Works Coal Tar...	16.67%	1.203	.0003125
Gas Works Coal Tar...	18.53%	1.205	.0003125
Gas Works Coal Tar...	27.50%	1.249	.0003100
Gas Works Coal Tar...	33.17%	1.296	.0002700
Coke Oven Coal Tar...	8.97%	1.185	.0003375
Coke Oven Coal Tar...	5.27%	1.193	.0003350
Coke Oven Coal Tar...	4.04%	1.178	.0003300
Coke Oven Coal Tar...	6.72%	1.195	.0003250
Coke Oven Coal Tar...	6.65%	1.197	.0003125
Coke Oven Coal Tar...	9.10%	1.203	.0003125
Coke Oven Coal Tar...	19.06%	1.258	.0003075
Coke Oven Coal Tar...	15.02%	1.231	.0003050

A New Natural Oxide. A. S. B. LITTLE. (*Progressive Age*, xxix, 101.)—The discovery is announced of a deposit of natural hydrated ferric oxide in this country similar and superior to the European deposits. It is active from the start, shows very high efficiency, and is readily revivified. Its great efficiency is due to the minute state of subdivision existing in the oxide between the ferric oxide and small quantities of silica, together with the water of hydration. It is thought that this ferric oxide may be used in suspension in water in closed vessels.

The Conservation of Wood Piles by the Injection of Zinc Fluoride. (*Génie Civil,* lviii, 465.)—Tests made by the Austrian Postal and Telegraph Bureau on treating pine, fir and spruce piles showed that acid zinc fluoride, $ZnFl_2$, was more efficacious than creosote. Dilute solutions were very quickly absorbed, variations in temperature below 50° C. having no effect. Another product for treating timber is mentioned, called "bellite," which is a mixture of sodium fluoride, dinitrophenol, and aniline.

Decomposition of Water by Zinc. M. KERNBAUM. (*Comptes Rendus*, clii, 1668.)—When zinc dust is shaken in water in the presence of air, hydrogen and hydrogen peroxide are produced, but in the absence of all traces of oxygen, the hydrogen peroxide is not formed. Hydrogen is formed whether oxygen is present or not.

Osmium as a Hardener for Platinum. ANON. (*Brass World,* vii, 230.)—Pure platinum is as soft as soft iron, and nearly all commercial platinum is hardened by adding iridium. W. C. Heraeus has found that osmium is superior to iridium for this purpose. It is stated that 2 per cent. of osmium imparts as much hardness as 5 per cent. of iridium, and a much greater elasticity. The presence of iron or copper considerably neutralizes the hardening effect of osmium. If more than 20 per cent. of osmium is present, the platinum alloy becomes brittle. The alloying must be done in a deoxidizing atmosphere, as osmium is easily oxidizable and the fumes are poisonous.

Koppers By-product Coke Ovens. W. E. HARTMAN. (*Mines Minerals,* xxxi, 185.)—The heat distribution is claimed to be better than in other types of by-product coke ovens, giving a very uniform quality of coke. The Koppers improved cross-regenerators raise the temperature of the air for combustion to 2000° F. Besides the high quality of the coke, the other claims for these coke ovens are: Economy in the use of gas for heating the ovens; the individual type of regenerator; the simplified construction and increased saving in all the by-products; and the simplicity of operation. Koppers patented direct process for the recovery of by-products is simple and more economical in operation than the older processes.

FRANKLIN INSTITUTE

BOOK NOTICES.

The Chemists' Pocket Manual. A practical handbook containing tables, formulas, calculations, information, physical and analytical methods for the use of chemists, chemical engineers, assayers, metallurgists, manufacturers, and students. By Richard K. Meade, Analytical and Consulting Chemist and Chemical Engineer. xii + 443 pages, 6 x 4 inches, leather. Second edition; price, $3.00. The Chemical Publishing Company, Easton, Pa., 1910.

In commercial chemical investigation, as in other branches of industrial research, economy of labor by expeditious methods is of prime importance and a set of notes describing processes and methods is as necessary to the chemist as the "pocket-book" is to the engineer.

Here, in a condensed form, are collected a large number of tables of chemical and physical data and explicit instructions for carrying out analytical determinations. The numerous references to original sources of information with each topic of the latter are a valuable feature when occasionally more detailed descriptions are desired. Much additional matter has been introduced in re-editing the work, making it more than double its former size.

Handbuch der Telephonie. Nach dem Manuskripte des Dr. Victor Wietlisbach, Weiland technischer Director des Schweizer Telephonwesens in Bern bearbeitet von Dr. Robert Weber, Professor der physik an der Akademie in Neuchatel. Zweite Auflage bearbeitet von Ingenieur Johannes Zacharias. 468 pages, illustrations, 8vo. Vienna, A. Hartleben, 1910. Price, in cloth, 12 marks.

The work is devoted to the consideration of telephony as it is at present carried on in Germany. Dr. Wietlisbach, who prepared the original manuscript, was at one time director of the technical department of the Swiss telephone systems, and the first editor, Dr. Weber, was a professor of physics.

The present edition has been thoroughly revised and considerably enlarged by the German engineer, Johannes Zacharias, and shows the results of the co-operation of the engineer and physicist.

Following the historical note and the consideration of the theoretical principles of telephony, the various telephone systems and apparatus are described and illustrated. The construction and mechanical details of the installations are given full consideration and the work closes with a chapter on wireless telephony.

Students of the subject will find much interesting information, especially as regards German practice.

LA MÉTALLOGRAPHIE APPLIQUÉE AUX PRODUITS SIDÉRURIGIQUES. Par Umberts Savoia, Ingenieur, Assistant de Métallurgie à l'Institut Royal Technique Supérieur de Milan. Ouvrage traduit de l'Italien. vi + 218 pages. 7½ x 5½ inches, paper covers, with 94 figures. Price 3 francs 25. Gauthier-Villars, Paris, 1910.

As a mode of readily determining the properties of metals and their alloys beyond the reach of physical test and chemical analysis, metallography has achieved a signal success and may now be classed as an indispensable method of the modern metallurgical laboratory.

The work here presented is the result of the author's personal study under the direction of noted French authorities and his subsequent experience in organizing a metallographic laboratory in the Milanese Steel Works. The methods and results presented consequently represent recent practice recorded from actual trial. About one-third of the work is devoted to fundamentals, the apparatus best adapted to the purpose and their manipulation. The subsequent chapters deal with particular investigations of a number of different ferric alloys. The bibliography appended to each chapter is a commendable feature.

LE BLANCHIMENT, CHIMIE ET TECHNOLOGIE DES PROCÉDÉS INDUSTRIELS DE BLANCHIMENT. Par A. Chaplet, Ancien Directeur d'usines et H. Rousset, Ingénieur-Chimiste. Paper covers, 171 pages. 7½ x 4½ inches, with 10 figures. Encyclopédie scientifique des Aide-Mémoire-Gauthier-Villars, Paris, 1910.

While it is in the textile industries that bleaching processes hold seemingly the foremost place, they are of equal importance in many other industries of lesser magnitude. In a condensed form the authors have sought to collect an account of the theory and practice applied to a variety of purposes not readily available by reference to recent technological works.

The book is divided into two parts. In the first, the principles of modern industrial methods as well as the treatments applied in the processes of bleaching are discussed. The second part is devoted to the description of practical methods employed and contains detailed information of processes applied to a variety of materials. The authors have not only compiled the data presented from available literature but have included the results of their own practical experience in this field.

MEMBERSHIP NOTES.

Changes of Address.

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NECROLOGY.

Mr. William Dunlap Sargent, 51 Remsen Street, Brooklyn, N. Y., died August, 10, 1911. He was born in Ligonier, Westmoreland County, Pennsylvania, July 2, 1845, the son of Elijah and Matilda (Tannehill) Sargent, and was educated in the public schools of Harrisburg, Pa., and, at an early age, became a telegraph operator in the service of the Pennsylvania Railroad. During the Civil War he served in the United States Military Telegraph Corps at General Burnside's headquarters in Cincinnati, Ohio. Later he became the manager of the Western Union Telegraph office at Harrisburg, Pa.; Assistant Electrician of the Western Union Telegraph Company in Chicago, Ill.; General Superintendent of the American District Telegraph in Philadelphia, Pa., where he installed the system.

Mr. Sargent entered the service of the Bell Telephone Company of Philadelphia, filling the office of General Superintendent and General Manager in the development of the business. Later he went to Brooklyn, N. Y., as General Manager of the New York and New Jersey Telephone Company, and while there was selected to represent the American Bell Telephone Company and to take charge of their exhibit at the Paris Exhibition in 1889.

Mr. Sargent was a director of the National City Bank of Brooklyn and of the Brooklyn Public Library. He was a member of the American Institute of Electrical Engineers, the Institution of Electrical Engineers, the United States Military Telegraphers' Association, The Franklin Institute, the Brooklyn Institute, the Pennsylvania Society, the New England Society, the Long Island Historical Society, the Manufacturers' Association, and of numerous clubs.

LIBRARY NOTES.

Gifts.

American Institute of Mining Engineers. Transactions, vol. 41, 1910. New York, 1911. (From the Institute.)

Canada Geological Survey Branch of the Department of Mines. Summary Report, 1910. Ottawa, 1911. (From the Survey.)

Victorian Institute of Engineers. Proceedings, vol. 9. Melbourne, 1911. (From the Institute.)

U. S. Department of Commerce and Labor. Statistical Abstract of the United States, 1910. Washington, 1911. (From the Department.)

Michigan Department of Labor. Second Annual Report, 1911. Lansing, 1911. (From the Department.)

Yale University Bulletin, Seventh Series, No. 8. President's Report. New Haven, 1911. (From the University.)

Ohio Geological Survey Bulletin 13, Fourth Series. Maxville Limestone. Columbus, 1910. (From the Survey.)

Illinois Bureau of Labor Statistics. Twenty-ninth Annual Coal Report, 1910. Springfield, 1911. (From the Bureau.)

Societe des Arts de Geneve, Comptes Rendus de L'Exercise, 1909-1910. Geneva, 1911. (From the Society.)

The Anschütz Gyro Compass. History, description, theory, practical use. Kiel, Germany, 1910. (From the Anschütz Co.)

U. S. War Department. Report of the Tests of Metals and other Material, 1910. Washington, D. C., 1911. (From the Department.)

U. S. Naval Observatory. Publications, Second Series, vols. 6 and 7. Washington, D. C., 1911. (From the Observatory.)

National Fire Protection Association. Proceedings of Fifteenth Annual Meeting, May 23–25, 1911, at New York. Boston, 1911. (From the Association.)

Waltham City Documents, 1910. Waltham, 1911. (From the City Clerk.)

U. S. Commissioner of Patents. Annual Report for the year 1910. Washington, D. C., 1911. (From the Superintendent of Documents.)

Wisconsin Geological and Natural History Survey. Bulletin No. 6, Scientific Series, "The Fossils and Stratigraphy of the Middle Devonic of Wisconsin," by Herdman F. Cleland, Ph.D.
Bulletin No. 7, Scientific Series, "The Inland Lakes of Wisconsin"; The dissolved gases of the water and their biological significance, by Edward A. Birge and Chancey Juday. Madison, 1911. (From the Survey.)

Leland Stanford Junior University Bulletin, May, 1911; Register for 1910–11. Stanford University, 1911. (From the University.)

Society of Naval Architects and Marine Engineers. Transactions, vol. 18, 1910. New York, 1911. (From the Society.)

Houston, Prof. Edwin J., "The Jaws of Death." Philadelphia, 1911. (From the Author.)

Meterologische Beobachtung in Moskau im Jahre, 1908 and 1909. "Die Variationen des Erdmagnetismus," "Ueber Erdmagnetische Ablenkungsbeobachtungen" von Prof. Dr. Ernst Leyst. Moscow, 1910. (From the Meteorological Observatory of the University of Moscow.)

Oklahoma Geological Survey. Bulletin 5, Preliminary Report on the Structural Materials of Oklahoma; Bulletin 7, Preliminary Report on the Clays and Clay Industries of Oklahoma, L. C. Snider, Norman, 1911. (From the Survey.)

U. S. Bureau of Statistics. Statistical Abstract of Foreign Countries. Parts 1–3, Statistics of Foreign Commerce, October, 1909. Washington, D. C., 1909. (From the Bureau.)

American Iron and Steel Association. Annual statistical report for 1910. Philadelphia, 1911. (From the Association.)

British Columbia Minister of Mines. Annual Report for 1910. Victoria, B. C., 1911. (From the Mines Department.)

Queensland Under Secretary for Mines. Annual Report for 1910. Brisbane, 1911. (From the Mines Department.)

Fornvännen 1910 Meddelanden fran K. Vitterhets Historie och Antikvitets Akademien. Stockholm, 1911. (From the Academy.)

University of Kansas. Forty-fifth Annual Catalogue for the year 1910–1911. Lawrence, 1911. (From the University.)

New York Public Service Commission. Proceedings, vol. 4, 1909. New York, no date. (From the Commission.)

New York Advisory Board of Consulting Engineers. Report to the Governor, 1910. Albany, 1911. (From the Board.)

Wisconsin State Historical Society. Original Papers No. 4, "The Chattanooga Campaign," by Michael H. Fitch; Original Papers No. 6, "Wisconsin Women in the War," by Ethel A. Hurn. Madison, 1911. (From the Society.)

The following collection of reports of the railroad commissions of various States was presented to the library by Robert D. Jenks, Esq.: Canada Board of Railway Commissioners, Report 1908 to 1910; Connecticut Railroad Commission, Annual Reports 1907 to 1910; Florida Railroad Commission, Annual Report 1910; Georgia Railroad Commission, Annual Report 1909; Illinois Railroad and Warehouse Commission, Annual Reports 1905 to 1909; Kansas Board of Railroad Commissioners, Report 1902, 1904 to 1910; Kentucky Railroad Commission, Annual Report 1906 to 1909; Louisiana Railroad Commission, Annual Report 1905, 1907 to 1910; Maine Railroad Commissioners, Annual Report 1906 to 1910; Michigan Railroad Commission, Annual Report 1907 to 1909; Minnesota Railroad and Warehouse Commission, Annual Report 1900 to 1910; Mississippi Railroad Commission, Biennial Report for two years ending June, 1909; Missouri Railroad and Warehouse Commission, Annual Report 1906 to 1910; Montana Railroad Commissioners, Annual Report 1907 to 1910; Nebraska State Railway Commission, Annual Report 1908 to 1910; Nevada Railroad Commission, Annual Report 1908 to 1910; New Hampshire Railroad Commissioners, Annual Report 1906 to 1910; North Dakota Commissioners of Railroads, Annual Report 1909–1910; Ohio Railroad Commission, Report 1906, 1908 to 1910; Oregon Railroad Commission, Annual Report 1908 to 1910; Rhode Island Railroad Commissioners, Annual Report 1905 to 1910; South Carolina Railroad Commissioners, Annual Report 1907 to 1909; South Dakota Board of Railroad Commissioners, Annual Report, 1909; Tennessee Railroad Commission, Report 1907, 1910; Texas Railroad Commission, Annual Report 1909, 1910; Vermont Board of Railroad Commissioners, Biennial Report June 1898 to 1900, June 1906 to June 1910; Washington Railroad Commission, Annual Report 1906, 1909, 1910; Wyoming State Auditor, Biennial Report 1903–04 to 1909–1910.

Purchases.

Aero Manual. 1910.
HARRISON, H. H.—Engineering Mathematics.
JOHNSON, V. E.—Theory and Practice of Model Aeroplaning.
CORDER, Geo. A.—Miner's Geology and Prospector's Guide.
IBBETSON, W. S.—Practical Electrical Engineering.
MARSHALL, P., ed.—Workshop Wrinkles and Recipes.
GENTRY, GEORGE.—Practical Electro-Plating.
TAYLOR, FRED H.—Private House Electric Lighting.
POWELL, F. E.—Windmills and Wind Motors.
JOHNSON, V. E.—The Gyroscope.
CROSS, H. H. U.—Care and Management of Ignition Accumulators.
THATCHER, E.—Simple Soldering.
LEECHMAN, D.—The Making of a Motor Car.
BROWN, C. W.—The Petrol Engine.
ASTON, W. G.—Model Flying Machines.
PEDLEY, G. F.—Motor Car Mechanics for Beginners.
Workshop Receipts. Vols. 3 and 4.
TOOKEY, W. A.—The Gas Engine.
EASDALE, W. C.—Sewage Disposal Works.
DE VRIES, D.—Milling Machines and Milling Practice.
SAMUELSON, A.—Flight Velocity.
WHITE, W. L. and G. M.—Heating Engineer's Quantities.
GISSING, F. T.—Commercial Peat.
TUNZELMANN, G. W. DE.—Treatise on Electrical Theory.
RUHMER, E.—Drahtlose Telephonie.
WORDEN, E. C.—Nitrocellulose Industry. 2 vols.
PÖSCHL, V.—An Introduction to the Chemistry of Colloids.
KALAHNE, A.—Grundzüge der Mathematisch-physikalischen Akustik.
LUNGE, G. and E. BERL.—Chemisch-technische untersuchungsmethoden. 3 vols.
VOIGT, W.—Lehrbuch der Kristallphysik.
GERARD, É.—Leçons sur l'électricité. 2 vols.
ZACHARIAS, J.—Elektrochemische umformer.
Encyclopædia Britannica. 11th edition, 28 vols.

PUBLICATIONS RECEIVED.

U. S. Geological Survey. Mineral resources of the United States. Calendar year 1909. Part I, Metals; Part II, Non-Metals. 2 vols., 8vo. Washington, Government Printing Office, 1911.

Canada Department of Mines. Annual report of the division of mineral resources and statistics on the mineral production of Canada during the calendar year 1909. John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 291 pages, 8vo. Ottawa, Government Printing Bureau, 1911.

U. S. Bureau of Mines. Miners' Circular No. 4. The use and care of mine-rescue breathing apparatus by James W. Paul. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

Message of the President of the United States in response to the resolution of the Senate dated June 27, 1911. 23 pages, map, 8vo. Washington, 1911.

Michigan College of Mines. Year Book 1910-1911. Announcement of courses for 1911-1912. 129 pages, maps and plates, 12mo. Houghton, Mich., College, 1911.

Sham Reciprocity and the Record of the Taft Administration. Remarks of Hon. Robert M. LaFollette, of Wisconsin, in the Senate of the United States, July 13, 1911. 15 pages, 8vo. Washington, 1911.

Safety as Applied to Grinding Wheels. Preventive and protective safeguards. Modern devices which can be practically applied in the use of grinding wheels and machines. 26 pages, illustrations, 12mo. Worcester, Mass., The Norton Company, no date.

U. S. Department of Agriculture. Forest Service, Bulletin No. 95. Uses of commercial woods of the United States: 1. Cedars, cypresses, and sequoias, by William L. Hall, assistant forester, and Hu Maxwell, expert. 62 pages, 8vo. Washington, Government Printing Office, 1911.

Royal Institution of Great Britain. Weekly evening meeting, January 27, 1911: Radioactivity as a kinetic theory of a fourth state of matter. Prof. William H. Bragg. 10 pages, 8vo. March 17, 1911: Water supply. John H. Balfour Browne, Esq., 18 pages, 8vo. April 7, 1911: A new method of chemical analysis. Prof. Sir. J. J. Thomson. 9 pages, illustrations, 8vo. June 9, 1911: Applications of physical chemistry to the doctrine of immunity. Prof. Svante Arrhenius. 27 pages, 8vo. London, Royal Institution.

U. S. Bureau of Mines. Technical paper No. 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 12 pages, 8vo. Washington, Government Printing Office.

Colorado School of Mines Magazine. July and August, 1911, vol. i, Nos. 10 and 11. Two pamphlets, illustrations, 8vo. Golden, Col. Colorado School of Mines Alumni Association.

Washington Academy of Sciences Journal, vol. i, Nos. 1 and 2, July 19, 1911. 48 pages, 8vo. Washington Academy of Sciences.

Bulletin du Comité Technique contre l'Incendie et les Accidents pour l'etude et la vulgarisation des moyens préventifs et de défense contre le feu et les accidents. Janvir, Février et Mars, 1911. 12 pages, 8vo. Paris, Comité.

U. S. Bureau of Mines. Technical paper No. 3. Specifications for the purchase of fuel oil for the government, with directions for sampling oil and natural gas, by Irving C. Allen. 13 pages, 8vo. Washington, Government Printing Office, 1911.

CURRENT TOPICS

Metallic Titanium. M. A. HUNTER and E. C. JONES. (*Rensselaer Polyt. Inst. Eng. and Sci. Series, No. 1.*)—Attempts to prepare pure titanium are described in detail, with a description of the properties of the metal obtained. The reduction of sodium titanifluoride by potassium yielded material containing 73.2 per cent. of titanium. A still poorer result was obtained with potassium and barium tetanifluoride. The reductions of titanium dioxide by carbon yielded a product never containing less than 4.6 per cent. of carbon. It is doubtful whether metallic titanium can be thus prepared, the product contains varying quantities of titanium carbide and monoxide. Nilson and Petersson produced titanium of 95 per cent. by reducing titanium tetrachloride with sodium. The authors obtained pure titanium by this method, taking extreme care to exclude air from the apparatus, a steel bomb with a clamped down lid. The reaction is also instantaneous when the bomb is heated to dull redness. The product gave 99.9 and 100.2 per cent. of titanium. The metal resembles polished steel. It is hard and brittle when cold, but can be easily forged at red heat. The melting point is between 1800° C. and 1850° C. Its specified gravity is 4.50.

Neon Incandescence Tubes. G. CLAUDE. (*Comptes Rendus*, clii, 1377.)—The author has devised a method for increasing the duration of incandescence of neon tubes without using an electromagnetic valve for the continuous supply of gas to the tube. In the case of tubes with very small electrodes, these volatilize rapidly, and the incandescence soon disappears. Tubes 5 metres long and 30 mm. in diameter, provided with hollow cylindrical copper electrodes, 60 mm. in length and 25 mm. in diameter, and traversed by alternating currents of 0.4 ampére, incandesced brightly for 6–8 hours. These electrodes however became heated nearly to bright redness, and a scaly deposit, resembling copper but more brittle, formed on the glass in their vicinity. This deposit, on treatment with nitric acid, yielded a gaseous residue which exhibited the spectra of hydrogen, of neon very distinctly, and that of helium very intensely; although the neon used in charging the tube was almost free from helium. This and other experiments, show that the rare gases obtained from the deposit are absorbed by the vaporized metal. Since the disappearance of the rare gases is due to the vaporisation of the electrodes, a diminution of this vaporisation will give a longer incandescence, and this can be brought about by the use of very large electrodes. With a tube 6 metres long, fitted with electrodes presenting a surface corresponding to 5 square dcm. per ampere, a period of incandescence of 400 hours was attained.

A Prize for a New Electric Lamp for Miners. (*Times*, London, May 27, 1911.)—The Secretary of State for the Home Department announces that to encourage the production of safe and efficient types of electric lamps for miners, a colliery proprietor has placed a sum of £1,000 at his disposal, as a prize for the best lamp or lamps fulfilling the requirements specified below. Mr. Charles Rhodes, a former President of the Institute of Mining Engineers, and Mr. Charles H. Merz, a member of the Departmental Committee on the Use of Electricity in Mines, have consented to act as judges. The conditions are as follows: 1. The competition is open to persons of any nationality. 2. It will be in the discretion of the judges to award the whole of the prize to the lamp they consider the best, or to divide the prize, or to make no award if no lamp appears to be of sufficient merit. 3. Lamps must be addressed, care of C. Rhodes, Esq., at the Home Office Testing Station, Rotherdam (Eng.), and must reach the testing station not later than December 31, 1911. A spare globe should accompany each lamp. The requirements are as follows: 1. The lamp should be of sound mechanical construction so as to withstand rough usage. 2. The lamp should be of simple construction and easy to maintain in good order and repair. 3. The lamp should be so constructed as to render impossible the ignition of inflammable gas either within or without the lamp. 4. The lamp battery should be so constructed that any liquid which it may contain cannot be spilled while the lamp is in use, and means should be provided for dealing with any gas which may be generated by the battery. 5. The materials used and the construction should be such that metals and other parts will not be liable to deterioration by corrosion as a result of the action of the electrolyte, etc., used in the battery. 6. The lamp should be effectively locked, so that it cannot be opened without detection. 7. The lamp should be capable of giving an amount of light of not less than 2-candle power continuously for a period of not less than 10 hours. 8. The light should be well distributed outside the lamp. A movable reflector to concentrate or shield the light may be provided. In addition to the above, regard will be paid to (a) the first cost of the lamp; (b) the cost of maintenance; (c) convenience in handling, and (d) the weight of the lamp when charged and ready for use.

Vanadium in Cast Iron. GEO. L. NORRIS. (*Iron Age*, lxxxvii, 1398.)—This is an interesting article. The chief points are: the primary purpose of adding vanadium to cast iron is not only the removal of oxygen and nitrogen, which it effects, but to increase the strength of the cast iron to which it is added from 10 to 25 per cent., depending on the initial strength of the iron. It causes a more even distribution of the graphite, with consequent greater freedom from both hard and porous spots, thus giving a finer and more uniform grain. In chilled iron vanadium produces a deeper, stronger and tougher chill, which is less liable to spall or flake. This chill is not so hard as the more brittle ordinary chill, and can be filed and machined more readily. Vanadium also toughens the iron and makes a superior cast iron. The usual amount of vanadium added to cast iron is 1/10 of 1 per cent. for cupola melted iron, or about 5 oz. of ferro-vanadium for each 100 lbs. Some foundries advocate a higher percentage, up to 15 per cent. For higher grade air furnace iron the addition of 0.18 to 0.20 per cent. of vanadium is recommended.

Washing Oils for the Removal of Naphthalene from Coal Gas. A. BAYER. (*J. Gasbeleucht,* liv, 496.)—For the removal of naphthalene from coal gas the author uses a light oil of the following composition: Benzene 0.4. light oil (100°–180°C.) 67.6, middle oil (180°–230°C.) 25.0, naphthalene 3.9, and heavy oil 3.1 per cent. This thoroughly removes the naphthalene and imparts light and middle oil to the gas, which seem to assist in the removal of naphthalene, which may have got into the mains. The naphthalene is found dissolved in the condensed hydrocarbons at various points in the system. Light oil gives much better results than heavy oil or than a mixture of heavy and middle oil.

Titanium in Iron and Steel. CHAS. V. SLOCUM. (*Amer. Mach.,* xxxiv, 1165.)—This interesting paper is worth perusal and may be summarized as follows: Small percentages of titanium will successfully produce many of the benefits of a large quantity. For instance, the use of two-tenths of 1 per cent. of alloy, containing 10 per cent. of titanium, that is, the use of 0.02 per cent. of metallic titanium, is frequently sufficient to clean the iron of the impurities remaining in the metal after the ordinary fluxes have accomplished all they can. Titanium removes the oxides and nitrides from molten iron, increases the fluidity, and makes the metal more homogeneous, so that the castings are closer grained, free from pin-holes and gas bubbles, and the iron has a denser structure and is easily machined. 0.1 to 0.2 per cent. of the alloy is sufficient to make viscous high-chilling mixtures come from the cupola close-grained and pour freely. The cost of the titanium is compensated by the use of less manganese and a trifle less silicon. The expense runs from 25c. per ton of castings up to say $3 as a maximum, which is often repaid in the reduction of bad work and in the improvement of poor irons. The same holds good for steel castings. One great advantage of the regular use of the titanium alloy is that it removes those features of irregularity which have given steel a bad name for its unreliability in certain directions. In a recent trial of the alloy in basic open-hearth by one of the large steel makers, it was found that 1½ per cent. of alloy was necessary to remove the last vestiges of brittleness and of blow holes, and this made the steel so dense that it was unusually strong, and became the source of much comment and investigation.

Alloys for Permanent Magnets. ANON. (*Amer. Machinist*, xxxiv, 1075.)—The addition of chromium to pure iron without carbon does not give good results, according to *Génie Civil*. An alloy containing 5 to 6 per cent. of chromium with 0.75 to 1 per cent. of silicon and 0.3 to 0.5 per cent. of carbon is excellent. An alloy containing 8 per cent. of molybdenum, 0.3 per cent. of vanadium and 0.6 per cent. of carbon makes good permanent magnets, which preserve their magnetic properties above 1000° C. Alloys of tungsten and iron are useless, except one which contains 4 per cent. of tungsten and 0.4 per cent. of vanadium; this makes an excellent permanent magnet.

Steam-boiler Economics. *Edit.* (*Eng. Record*, lxiii, 689.)—Mr. Geo. H. Barrus reviewed the results of 30 years' experience in steam-boiler testing, in a paper read before the Congress of Technology at Boston, Mass. This is a paper worthy the attention of steam-users. Its main points may be recommended thus: The economy resulting from the admission of air over the fuel bed, in a boiler of the horizontal return tubular type, is stated to be such that the evaporation per pound of combustible was increased 10 per cent., from 10.23 to 11.35 lbs. from and at 212° F.; the draft between damper and boiler being about 0.3 inch, and the temperature of the escaping gases was 510° F. with air admission, and 515° F. without it. The disadvantages of a thick fuel were clearly shown. With a fire-thickness of 12 inches the percentage of carbon monoxide in the gases was 1.1 compared with 0.1 with a 6 inch fire, and the evaporation was 11.5 lbs. with the thicker fire and 12 lbs. with the thinner. The importance of a clean heating surface is clearly shown. Incomplete combustion is often responsible for relatively low efficiency. Forcing the output reduces the efficiency. Interior scale and neglect in maintenance also result in low evaporation.

To Prevent Dusting of Concrete Floors. ALBERT MOYER. (*Eng. Record*, lxiv, 16.)—After washing thoroughly with clean water, and scrubbing with a stiff broom or scrubbing brush, allow the surface to dry and apply a solution of one part water glass (sodium silicate), 40° Beaumé, and 3 to 4 parts water, the proportion of water depending upon the porosity of the concrete in the floor surface to be treated.

Travel of Particles in Electric Field. G. Reboul and E. G. de Bollemont. (*Comptes Rend.*, clii, 758.)—If copper and platinum electrodes, separated by mica, are heated, a deposit of copper oxide is found on the platinum. Its contour is similar to that of the copper, so that the particles are projected across. The amount of deposit reaches a maximum in a time ranging from 30 minutes at 400° C. or above to 30 seconds at 900° C. Thereafter the deposit continually disappears. The distance between the electrodes must be under 3 mm.; within this limit the smaller the distance the greater the deposit. The condition of the surfaces has considerable effect on the results.

Ionisation of Gases by Light Emitted from Geissler Tubes. H. G. Connegieter. (*Konink. Akad. Wetersch, Proc.*, xiii, 1114.)—If it is considered that the action of ether vibrations upon the molecules of substances is a resonance effect, then if molecules on which the light shines are struck by vibrations the period of which corresponds to those which the electrons in molecules can emit themselves under certain conditions, the electrons will acquire by resonance so strong a motion that they are loosened from the molecule and behave like free particles. From this point of view it may be expected that if a given substance in the luminous state emits electrically active rays, this substance, when struck by these particular rays will be more photo-electric than when under the influence of rays from any other source of light. The apparatus used in the experiments consisted of three parts: (a) the discharge tube, (b) the absorption space, and (c) the ionisation chamber, all of which are air tight, and can be filled with any desired gas. By this arrangement it is possible to examine the absorption of different gases for the ionising rays, and to study the connection between absorption and ionisation. The effects caused by hydrogen, nitrogen, and carbon monoxide radiation are dependent on the pressure of the gas; the mutual proportion of the effect on the different gases varies with the pressure of the gas. The values of this proportion show that when the pressure is high the ionisation is always strongest in hydrogen, then in carbon monoxide, nitrogen, air and oxygen in order. The proportion changes when the pressure in the gas is lowered.

The Rays of the Alkaline Metals. E. Hanriot. (*Moniteur Scient.*, 834, 410.)—Potassium salts have a very penetrating ionising radiation; the radiation of the rubidium salts is less penetrating, but more intense; on the other hand the cœsium salts have never shown any appreciable ionisation, which is very unexpected considering the close relationship of these three metals. It is natural to ask if the electrons emitted with such high speed by potassium, and with a lower speed by rubidium, are not also emitted by cœsium, but with an energy insufficient to produce ionisation. Experiments have been made in this direction by means of a charged electroscope, placed above a layer of a salt of one or other of these three metals; when the electroscope was positively charged, it gave an appreciable deflection with potassium or rubidium salts, but no deflection or at best only doubtful, with cœsium salts.

Water Softening by Aluminum Plates. T. R. DUGGAN. (*Eng.* cxi, 392.)—This method was discovered by Brandes and is known as the "Luminator" process. The water is allowed to run down an aluminum plate of special dimensions, with corrugations of a particular size, according to the character of the water under treatment. No chemicals are used; all that is required is to keep the corrugations well brushed and clean from the deposit. When the storage tanks and mains are far from the boiler, they should be coated with a non-conducting composition, and the water should reach the boiler as soon after treatment as possible. Storage tanks should not be too large, as the water should be used within seven days after treatment to get the maximum effect. When water is passing continuously, day and night, it may be necessary to give the apparatus a rest about one day per week to avoid polarisation of the plates. The passage of the water over the channels at certain speeds induces a current of electricity, the water being negative and the plates positive, and the salts are ionised, and assume the amorphous instead of the crystalline form. At the same time the aluminum, through friction and the electrical action, is abraded from the surface as a colloid, which undergoes change in the water. F. G. Donnan found but little aluminum hydroxide in the treated water, but the ultra-microscope showed colloidal aluminum mixed with hydroxide. Water thus treated deposits much less scale: old scale is softened and detached from the plates, especially the flues: steam is drier; less coal is needed for steam-raising, and the salts are found as powder in the bottom of the boiler. It is important that boilers should be regularly blown off, particularly when the apparatus is first installed, as the old scale comes down so rapidly that the plates may become overheated from its accumulation, unless it is quickly removed. After the old scale is removed, this danger ceases, as only mud is found in the boiler, and the water is in contact with the plates and tubes. If the boiler is systematically blown off, little or no mud will be found in it. Priming is much less, or quite eliminated, by the use of this apparatus.

Bronze and Iron Articles of the La Tene Period. H. RUPE. *Verh. Naturf. Ges. Basel*, xxi, 40.)—Bronze and iron particles from the graves of Tessin were examined. About 11 per cent. of the bronzes examined contain 90 per cent. copper and 10 per cent. tin. About 5 per cent. contain only 1.5 per cent. of tin or less, which indicates they were made from a copper ore containing tin. The analysis of the iron articles leads to the following deductions as to their origin, age and workmanship. Irons with high phosphorus or sulphur were found in the territory of the present Switzerland; those with low P and S were probably imported from Etruria. The photographs of etchings from prehistoric iron lead to the inferences that the iron of the La Tène period was not completely fused.

Aluminum Windings for the Field Magnets of Traction Motors. A. Mariage. (*Lumière, Electr.*, xiv, 104.)—Experiments are being made with aluminum instead of copper conductors on the field magnets of motors for traction purposes. The advantages of aluminum are its lightness and cheapness; the economy is about 60 per cent. The cost of renewals is less than that with copper, and the effects of vibration are not so marked. The disadvantages are the cost of soldering and the greater bulk.

Production and Uses of Zinc Dust. P. Speier. (*Mining Sci.*, lxiii, 38.)—Zinc dust is obtained in the reduction of spelter by means of special collectors. The quantity of zinc dust recovered in proportion to the production of spelter depends on the furnace charge as well as on the temperature of the distillating furnaces, and may become as high as 10 to 15 per cent. of the spelter produced. To be merchantable it must contain about 90 per cent. of zinc. It is used for various purposes in the industries, e. g., for reducing indigo blue and nitro-benzene, for purifying fats, for bleaching glue, in the Cowper-Coles galvanizing process, for the extraction of gold in the cyanide process, and so on. Drewsen's method is recommended for the analysis of zinc duct, which is based on the power of finely divided zinc to reduce a solution of chromic acid without generating hydrogen.

Effect of the Dust of Tarred Roads on the Eyes. L. Philibert. (*Rev. Gen. Sci.*, xxii, 207.)—Ordinary calcareous or siliceous road dust causes only a slight inflammation. That from tarred roads causes chronic inflammation and conjunctivitis. This is chiefly due to the carbolic and phenolic vapors of freshly laid tar. Oil is proposed as a substitute.

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ELECTROLYTIC CORROSION OF IRON BY DIRECT CURRENT.

BY

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IN electric railways the rails are practically always used as return conductors. Since they are grounded, a part of the return current leaves the rails and passes through the ground, and if the voltage drop in the rails is considerable this stray current through the ground may be considerable and cause more or less serious corrosion of rails, gas and water pipes, iron structures and other metal parts located in the ground. The problem of studying the corrosion produced by stray direct currents in the ground, so as to reduce the damage caused by them to a minimum, thus is of great importance.

This problem is frequently attacked by measuring the potential difference between the different points of the rail return system and other metal parts in the ground, estimate therefrom the stray current, and from this judge on the amount of electrolytic corrosion which may be expected by Faraday's law. There is, however, some doubt, from the experience of electric railways, whether the passage of a stray current between metal parts in the ground necessarily involves corrosion in accordance with Faraday's law, or whether it may not be possible that currents

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pass from metal to ground without corresponding corrosion of the metal.

As iron is the metal which is most frequently exposed and therefore of greatest importance, an investigation was started on the corrosion of iron under the influence of an electric current in Dr. Steinmetz's laboratory, and some preliminary results are given in the following:

The first electrolyte experimented with was a 1 per cent. solution of ammonium nitrate, as nitrates and ammonia salts are the most probable conducting compounds in soils, especially in cities.

Sheet iron plates of 0.6 mm. thickness were used, carefully cleaned by hydrochloric and nitric acid and then mechanically. They were immersed in quart jars, each containing approximately 800 cc. of electrolyte.

The plates dipped 9 cm. into the electrolyte.

As negative were chosen plates of 14 cm. length, 5 cm. width, giving 90 cm.^{2} submerged surface.

As positive were chosen plates of 14 cm. length and of different widths, from 0.6 cm. to 10 cm.

The current was maintained constant, from a storage battery, at .040 ampere, corresponding to current densities from 36 amperes to 2.2 amperes per m^2.

After the test the plates were carefully cleaned with distilled water and chalk, and then weighed again.

In calculating the theoretical corrosion, the value of .29 mg. of iron per coulomb was used.

The duration of this test was 98 hours.

The corrosion in no case approached the theoretical value, but varied from one-tenth to one-third of the theoretical value, as follows:

In general, it was lower at higher current densities.

Herefrom it seems to follow that it is not feasible to estimate the electrolytic corrosion of iron structures in the ground from the amount of stray current passing from these structures.

Current density, amperes per m^2	36	18	9	4.5	2.25
Corrosion, per cent. of theoretical ..	10.5	18.0	17.1	35.1	34.2

As the electrolytic corrosion of the iron was found much lower than the theoretical value, tests were made to see whether this is due to a partial corrosion, or due to periods in which no corrosion takes place, that is, the iron is "passive," and to find the conditions under which the iron is passive, that is, does not corrode as positive terminal.

For this purpose, 10 cells were made up, 800 cm.^{3} electrolyte, 1 per cent. solution of ammonium nitrate, with iron plates of 14 cm. x 1.25 cm., dipping 9 cm. into the electrolyte, and operated in series, with 50 milliamperes of current, corresponding to a current density of about 22 amperes per m^2.

In two cells the plates were taken out, cleaned and weighed very frequently, in two cells less frequently, and in two cells left in continuously. In two cells the plates were put in the electrolyte one hour before the current was put on; two cells were left without current and used to observe the spontaneous or chemical corrosion of the plates by the electrolyte.

In half the cells the electrolyte was changed after the cell had been running 24 hours; in the others the electrolyte was not changed.

The results of this and the following test are given in Table I, and some are plotted in Figure 1.

It seems that there is no partial corrosion, but the iron is either *passive*, that is, practically no corrosion at all takes place, or the iron is *active*, that is, the full theoretical corrosion occurs. Fractional values of the theoretical corrosion are observed only where the cell has been operated continuously for a considerable time, and apparently had started active and then become passive.

The average corrosion during the active periods is 49.6 mg. per hour, or, if counting only the shorter periods—during which a change of state is less probable—55.1 mg. per hour, while the theoretical attack is 52.2 mg. per hour, and is shown by the dotted lines in Figure 1.

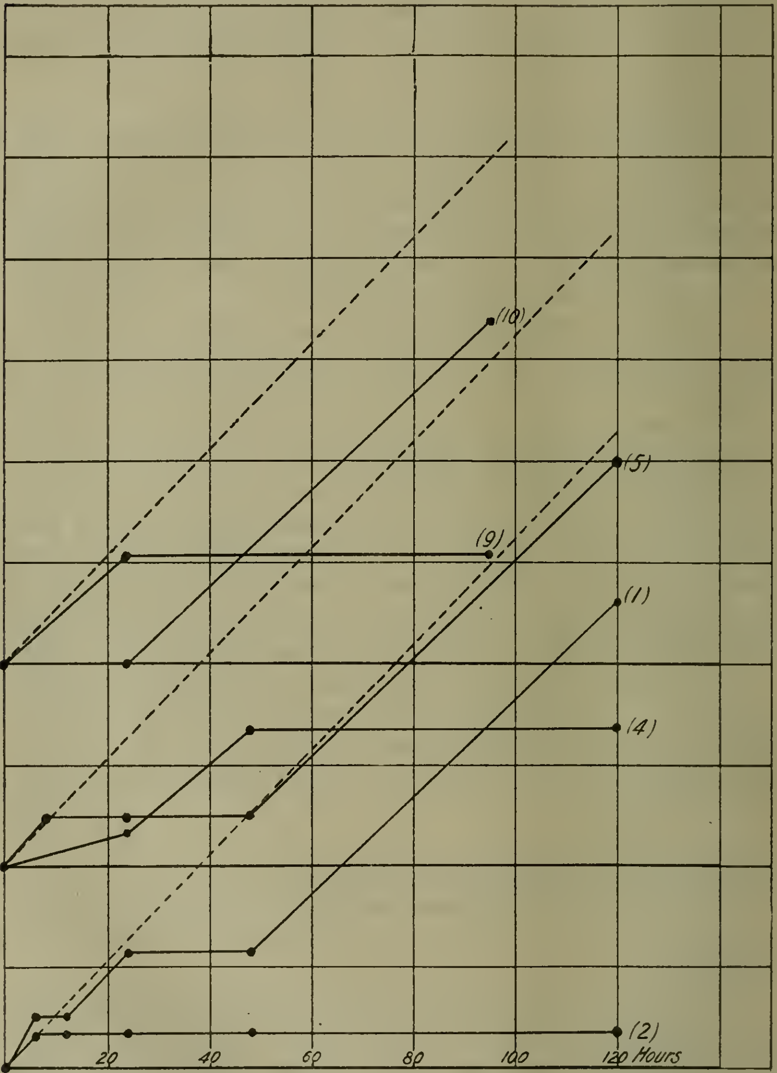
The average chemical corrosion (without current) is 1.85 mg. per hour, or 0.82 per m^2 an hour.

The corrosion of the anode during the active period thus is somewhat greater than the theoretical, as expected from chemical corrosion.

The average corrosion of the anode during the passive period is .20 mg. per hour, that is, less than ½ per cent. of the theoretical, and is only about 11 per cent. of the chemical corrosion. That is, the passage of a current from a *passive anode* protects the same from spontaneous or chemical corrosion.

The average corrosion of the cathode was .40 mg. per hour with a *passive* anode, and .23 mg. per hour with an *active* anode.

FIG. 1.



Electrolytic corrosion of iron by direct current. 1 % ammon. nitrate solution, 22 amp. p. m².

That is, if the anode is passive and does not corrode, the cathode corrodes about twice as much as if the anode is active and corrodes. Even in this case, however, the corrosion of the cathode is only about 20 per cent. of the chemical corrosion, and about twice as much as that of the anode.

It thus follows that during the passive state the corrosion of two iron plates is by the passage of the current reduced to a small fraction of the chemical corrosion. That is, under certain conditions (passive state), the passage of a direct current protects both of the iron terminals between which it passes.

The active state occurred eight times.

The passive state occurred ten times.

Three times the corrosion was intermediate between that of the active and the passive state. Of these, two were long continuous runs, in which the behavior of the cells made a spontaneous change from the active to the passive state probable.

Handling the plates, that is, taking them out, cleaning and weighing, frequently changes the state:

6 times from active to passive,
4 times from passive to active,
3 times the plate remained passive,
Possibly 1 time the plate remained active.

Change of electrolyte changed

1 time from passive to active,
1 time left the plates passive,
1 time probably left the plates active,
1 time probably changed from passive to active.

No definite effect of a change of the electrolyte on the state of the plates is thus shown. As at the end of the run the electrolyte still gave the ammonia reaction and the nitric acid reaction, this is reasonable.

The voltage per cell was either low, about 1 volt, or high, 2.7 volts, but intermediary voltages were observed only in two cases, at the end of a long active run, probably as the result of an increase of the resistance of the electrolyte.

The active state of corrosion was always accompanied by low voltage; the passive state, of no corrosion, by high voltage; and the voltage of the cell was found a good indicator of its state, and where a cell changed from active to passive state this was shown by the rise of voltage.

The electrolyte and the deposit formed in the cell seem to give an indication of the state of the anode:

In all cells in which the anodes were passive at least during most of the time, and more particularly the latter part of the run, the electrolyte was clear, or only slightly yellow, and only little deposit was formed, of a yellow-brown color, apparently ferric hydrate.

In all cells in which the anodes were active and greatly corroded the electrolyte was very dirty, and masses of deposit formed. This deposit was of a dirty greenish-black color, indicating apparently ferrous hydrate.

Interesting was one cell in which active corrosion had taken place, but towards the end of the run the voltage had become high and the anode apparently passive. This cell also had a dirty electrolyte and a very large amount of deposit, but the deposit had turned brownish-black towards the end of the run, consisting apparently largely of ferric hydrate. It seems that during the passive period the deposit of ferrous hydrate, formed during the preceding active period, had been oxidized to ferric hydrate.

It thus seems that the active state is accompanied by the formation of the lower hydrates of iron, of greenish-black color, while during the passive state only the higher ferric hydrate can exist.

To investigate how the passive and active state of the iron depend on the method of starting the current, and more particularly whether starting under high current produces passivity, and immersion in the electrolyte without current activity, four cells were started at high current density, and the current then reduced. The series resistance was greatly reduced, the plates then put into the cell without electrolyte, and the electrolyte poured in while the voltage was on, so that the current started simultaneously with the immersion of the electrolyte, at about 430 amperes per m^2. The current was immediately reduced to the normal value of .05 ampere, or 22 amperes per m^2.

All three cells were immediately passive, gave high voltage, and gas on the positive electrode. The positive plate remained bright, the negative turned yellow by a thin yellow deposit of ferric hydrate.

After three hours' running, one cell was short-circuited for one hour and the electrolysis then continued for 14½ hours more. After the short circuit, the voltage was low, the cell active, and after weighing the plate the corrosion was found, the theoretical amount corresponding to the active period.

A second cell was started once more, in the same manner, and again found passive, with no appreciable corrosion, and high voltage.

Then two cells were made up, by heating the passive plates in the Bunsen flame to incandescence, until covered with a thin layer of scale (18 and 27 mg.), and one cell started immediately, the other after immersion in the electrolyte for one hour, but in both cases the start was made at excess current and the current immediately reduced. Both cells gave high voltage, 2.7, and showed no corrosion, during a long run (118 hours).

After 44½ hours' run one of the cells was once more short-circuited for two hours and the run then continued. The cell remained passive, the voltage high, and practically no corrosion.

Herefrom it seems:

(1.) Starting with the power on, so that the current starts simultaneously with the immersion of the iron into the electrolyte, causes the passive state of no corrosion, at least if the current density in the moment of start is high.

(2.) Submersion of the plate in the electrolyte for some time before the start, or remaining in the electrolyte without the current on for some time during the run, tends to produce the active state.

(3.) The presence of scale on the plates does not seem to have any effect in producing the active state.

(4.) During the passive state only ferric hydrate appears in the cells, on negative plate and in the electrolyte, while the active state always seems to be coincident with the formation of ferrous compounds, though, if followed by the passive state, these ferrous compounds are converted into ferric hydrate.

Thus far only 1 per cent. solution of ammonium nitrate, cp. cryst., had been used as electrolyte.

To investigate other electrolytes, 18 cells were made up, of standard size plates: 14 x 1.25 cm. 1 per cent. solutions of various electrolytes were used, all cp. cryst., and of each electrolyte two cells were made up, one being connected into the circuit on 0.02 ampere (9 amperes per m^2), the other left as check of the chemical corrosion.

The order of electrolytic corrosion, in per cent. of the theoretical value, during a run of 70 hours, was found:

TABLE I.

		Mg. per hour	Avg. volts
Potassium bichromate	.34%	= .07	4.1
Potassium carbonate	2.75	= .58	3.7
Potassium nitrate	25.0	= 5.25	2.5/3.5
Ammonium nitrate	37.8	= 7.93	.8/2.4
Ammonium carbonate	38.2	= 8.0	2.5/3.7
Potassium chloride	102.2	=21.5	1.9
Ammonium chloride	102.3	=21.5	1.3
Ammonium sulfate	102.7	=21.6	3.7
Potassium sulfate	102.8	=21.6	1.9

The order of chemical corrosion in the check cells is, in mg. per hour:

TABLE II.

	Mg. per hour	Mg. per m^2 per hour
Potassium bichromate	.01	=0.004
Potassium nitrate	.34	=0.15
Potassium carbonate	.36	=0.16
Potassium chloride	.55	=0.245
Potassium sulfate	.59	=0.26
Ammonium carbonate	.61	=0.27
Ammonium sulfate	.64	=0.285
Ammonium chloride	.91	=0.405
Ammonium nitrate	1.75	=0.78

Potassium carbonate, nitrate and bichromate give gas at both plates.

Potassium chloride and sulfate, and ammonium sulfate and carbonate give gas at the negative, but not at the positive plate. In ammonium chloride and nitrate the electrolyte became so muddy that the plates could not be seen.

In potassium bichromate and carbonate the electrolyte remained clear and colorless; in potassium nitrate, chloride and sulfate it remained fairly clear, but slightly yellow; in ammonium sulfate, nitrate and carbonate slightly muddy and slightly yellow; in ammonium chloride the electrolyte became opaque greenish-black.

The deposit was large and greenish-black in potassium and ammonium sulfate and chloride, showing ferrous hydrate. In these the corrosion was the theoretical.

Potassium bichromate gave no deposit; potassium nitrate and carbonate, and ammonium nitrate and carbonate a light brown deposit: ferric hydrate.

Of special interest are potassium nitrate, ammonium nitrate and ammonium carbonate: all three give a corrosion, which is appreciable, but only a part of the theoretical, from 25 to 38 per cent., and all three show a sudden voltage rise during the run. It thus is safe to assume that with these three electrolytes the cells start active, but become passive during the earlier part of the run.

From these tests it seems to follow:

(1.) Potassium bichromate and potassium carbonate give the passive state of high voltage and no corrosion.

(2.) The chlorides and sulfates give the active state, showing the theoretical corrosion.

(3.) With potassium nitrate, ammonium nitrate and ammonium carbonate an active as well as a passive state may exist, and—in accordance with previous tests—the tendency is to change from the active to the passive state, and probably to start active. In the passive state the voltage is higher than in the active state, and the change from active to passive state is always accompanied by a considerable voltage rise.

(4.) Activity is always accompanied by the formation of the greenish-black ferrous compounds, which never appear during the passive state, but during the passive state only the yellowish-brown ferric compounds appear. At a change from the active to the passive state the ferrous compounds existing in the electrolyte, etc., are rapidly oxidized to ferric compounds.

It thus seems:

Iron in the ferric state is passive, in the ferrous state is active. Electrolytes in which ferrous compounds form, as chlorides and sulfates, give active corrosion. Electrolytes in which ferrous compounds do not form or can not exist, as bichromates, always give the passive state. Electrolytes of acids which give unstable ferrous salts, as the nitrates, may give the active as well as the passive state, but the tendency is towards the passive state; that is, even if the corrosion begins with the formation of ferrous compounds, these are oxidized to the ferric state, and then the activity ceases.

Possibly ferric hydrate is electro-positive towards iron, and thus, if once ferric hydrate appears on the positive plate, this plate is protected, as the nascent oxygen then appears at the ferric hydrate and not at the iron; that is, the current issues from the former and not from the latter, and thus no corrosion occurs, as the iron is at a negative potential and thus protected.

Any solvent of ferric hydrate thus would destroy passivity.

Since some compounds, as bichromates and nitrates, tend to produce passivity, that is, protect the iron against electrolytic corrosion, while other compounds, as ammonium chloride, cause activity, that is, give full theoretical electrolytic corrosion, experiments were made to determine whether by the presence of passivating agents, bichromates and nitrates, iron can be protected from corrosion in the presence of activating compounds, as ammonium chloride, or, inversely, how large an amount of ammonium chloride is necessary to destroy the passivity given by bichromates and nitrates.

A run was made on five cells, containing a 1 per cent. ammonium chloride solution, to which was added in one cell 1 per cent., in another .1 per cent. of potassium bichromate, to the third cell 1 per cent., the fourth .1 per cent. of potassium nitrate, while the fifth cell contained only the 1 per cent. of ammonium chloride. The results showed, by the low voltage and the loss of weight, active corrosion throughout; that is, an amount of bichromate or nitrate, equal to that of ammonium chloride, does not reduce the active corrosion, has no protecting action yet.

A second test was made by using two cells with a 1 per cent. solution of potassium bichromate, the one containing in addition 1 per cent., the other .1 per cent. of ammonium chloride, and two cells with a 1 per cent. solution of potassium nitrate and the same amount of ammonium chloride. The results also showed active corrosion, equal to the theoretical amount and even slightly more, and low voltage on the cells.

Thus an amount of bichromate or nitrate, equal to 10 times that of ammonium chloride, does not yet give any protection against electrolytic corrosion, and, inversely, an amount of activating agent, equal to one-tenth of the passivating agent, destroys the passivity.

This second test was repeated by starting with excess current and with electrolyte containing only the bichromate or nitrate, so as to produce passivity at the start, and after starting the ammonium chloride was added. The voltage immediately dropped and active corrosion began, and continued by the theoretical amount.

A series of tests was therefore undertaken to determine how small a quantity of activating agent is sufficient to destroy passivity. Four cells were made up, two with 1 per cent. potassium bichromate, two with 1 per cent. potassium nitrate solution, started with excess current, and run for some days. The high voltage and the absence of any visual attack showed passivity. Then .01 per cent. respectively .02 per cent. ammonium chloride was added and the test continued for some days. The voltage remained high, and the iron passive. Then once more the same amount of ammonium chloride was added, giving a total of .02 per cent. respectively .04 per cent., or 1/50 respectively 1/25 as much as the amount of passivating agent. The bichromate cell with .02 per cent. NH_4Cl remained passive, but that with .04 per cent. showed some corrosion, and gave a lower voltage. The nitrate cell with .02 per cent. NH_4Cl retained high voltage, but showed slight corrosion, while the cell with .04 per cent. showed full activity, corrosion and low voltage. The plates were then taken out, weighed and put back and the run continued, except with the last cell, in which the iron plates had been eaten too far. This second run gave the same results. That is:

In a 1 per cent. potassium bichromate solution, .02 per cent. ammonium chloride does not yet give any corrosion, but .04 per cent. gives a slight, though appreciable, corrosion.

In a 1 per cent. potassium nitrate cell, .02 per cent. ammonium chloride gives a slight corrosion, .04 per cent. gives full activity.

Thus, 4 per cent. as much ammonium chloride as potassium bichromate, and 2 per cent. as much ammonium chloride as potassium nitrate, appear to be about the limit up to which passivity can be retained; that is, at this percentage an appreciable corrosion begins. Or, inversely, to protect the iron against electrolytic corrosion in the presence of ammonium chloride requires at least 25 times as much potassium bichromate, or 50 times as much potassium nitrate, as ammonium chloride.

Protection against electrolytic corrosion in the presence of very active corroding agents, as ammonium chloride, can not be produced by the addition of passivating agents, as bichromates and nitrates, except if excessive amounts of the latter are used.

As previous tests have shown that an extremely small percentage of chloride—.02 respectively .04 per cent. of ammonium chloride—is sufficient to destroy the passivity produced in a 1 per cent. potassium bichromate or nitrate solution, a corresponding test was made with ammonium sulfate.

Three cells were made up with a 1 per cent. potassium bichromate solution, and three cells with a 1 per cent. potassium nitrate solution. One of each kind was run without addition, as check cell, while to the other two various amounts of ammonium sulfate solution were added, giving percentages of ammonium sulfate from .01 per cent. to .66 per cent. (in addition to the 1 per cent. of potassium bichromate respectively nitrate). The cells were always started at high current.

The results showed passivity throughout; that is, .66 per cent. of ammonium sulfate does not yet destroy the passivity, while .04 per cent. ammonium chloride does, and the chlorides thus are many times more powerful activating agents than the sulfates.

Interesting to note is that in several instances some corrosion occurred in the potassium nitrate cell, and apparently this cell had started active, but soon became passive. The bichromate cell was always passive. Bichromates thus are more powerful passivating agents than nitrates.

Finally .02 per cent. and .04 per cent. of ammonium chloride was added to the cells containing respectively .33 and .66 per cent. of ammonium sulfate, and 1 per cent. of potassium bichromate respectively nitrate. The nitrate cells became active and gave complete corrosion, and the same also the bichromate cell with .04 per cent. chloride, while the bichromate cell with .02 per cent. chloride still remained passive, but gave a slight corrosion.

To investigate the effect of ammonium sulfate still further. 12 cells were made up containing 1 per cent. ammonium sulfate and various percentages of potassium nitrate and bichromate.

The results were somewhat erratic, but in general showed that 1 per cent. and occasionally even .5 per cent. of nitrate or bichromate added to 1 per cent. of ammonium sulfate makes passivity possible under favorable conditions, as when starting at high current density, while activity tends to result from an interruption of current when the plates are in the electrolyte.

Thus the sulfates, while being activating agents, that is, complete theoretical corrosion of the iron occurs in them, are very much less powerful than the chlorides, and from 50 to 100 per cent. of passivating agents, as nitrates or bichromates, are sufficient to produce passivity under favorable conditions, and a protection against them thus appears possible. Chlorides, however, are extremely powerful activating agents, and an extremely small percentage of them is sufficient to make passivity impossible; chlorides apparently are about 25 times as powerful as sulfates in destroying passivity.

To determine whether alkaline reaction of the electrolyte protects the iron against electrolytic corrosion, three cells were made up with a 1 per cent. solution of ammonium chloride and three cells with a 1 per cent. solution of ammonium sulfate. Of both kinds, one cell was left without addition, to the second was added 1 per cent. of slaked lime CaO_2H_2, to the third 1 per cent. of chalk powder $CaCO_3$.

The tests showed that $CaCO_3$ exerts no protective action, while CaO_2H_2 exerts a material protective action with ammonium sulfate, but very little with ammonium chloride; in the presence of CaO_2H_2 the electrolytic corrosion in ammonium sulfate is reduced to less than one-half (42 per cent. of the theoretical), and half of the voltmeter readings are high, half are low. Apparently the cell started passive, and became active after some time.

With ammonium chloride the reduction of corrosion by CaO_2H_2, equal in amount to that of the NH_4Cl, is only 6 per cent., hence almost no protective action yet.

To investigate the electrolytic corrosion which may be expected in iron in the ground, some tests were made with dirt solution as electrolyte, but the tests were not conclusive, and had to be postponed for lack of time.

The preceding investigation is very far from complete, and not too much reliance must be placed on the numerical values, for instance the effect of chlorides or sulfates on nitrates and bichromates, etc., as they are based on a small number of tests only, and a number of conditions, which are of influence, have not yet been studied, as the concentration of the electrolyte, the current density, the effect of circulation (which is possible in the solution of the electrolyte, but would be practically absent in the soil), the temperature, etc. However, some general conclusions appear warranted:

(1.) No conclusion can be drawn on the electrolytic corrosion of iron from the amount of current which passes from the iron as anode, since iron may assume a passive state, in which electrolytic corrosion is entirely absent, or an active state, in which the corrosion follows Faraday's law.

(2.) The conditions which lead to the active or to the passive state are not yet fully understood, but sometimes, under apparently identical conditions, either state may occur.

(3.) Alkaline reaction of the electrolyte, the presence of nitrates, and, more still, bichromates, tend to produce the passive state; sulfates, and especially chlorides, even in small quantities, produce the active state of electrolytic corrosion.

(4.) High current density, even if only momentary, tends to produce the passive state, absence of current the active state.

(5.) In the active state the products of corrosion are initially ferrous compounds, in the passive state ferric compounds, and the passive state occurs in such electrolytes in which ferrous compounds cannot exist or are chemically unstable.

(6.) In the passive state the potential difference at the electrodes is much higher than in the active state.

Balaklala Smelter and Cottrell Fume Controller. A. H. Martin. (*Mining Sci.,* lxiii, 337.)—The production of fine dust in the blast furnace is reduced to a minimum by treating only the coarse ore in the blast furnace, and the fines in the roasting and reverberatory furnace. The fumes are received in flue chambers and pass through the Cottrell fume controller to the stack. This controller consists of a series of positive electrodes which arrest the solid particles carried off by the gases. The steel electrodes are the positive poles of the plant and the negative poles are micanite rods. As the electric current leaps across to the negative micanite poles, the solids are deposited on mica saw teeth. An automatic jarring device causes the particles to fall into hoppers below.

Cost of Street Lighting by Gas and Electricity. H. T. Lee and D. Stuart. (*Elect. Eng.,* vii, 165.)—The cost of lighting the streets in a number of places, including the cost of renewals, repairs and attendance, is stated in terms of the cost per candle-power per year. The figures vary greatly in different places, but the average seems to show that on the candle-power basis gas cost about 2½ times as much as electricity.

THE RÔLE OF WATER IN MINERALS.*

BY

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CONTENTS.

PAGE
Introduction 309
The Function of Water in Substances 311
The Criterion Used in the Present Method of Analysis 315
The Least Thickness of Water Detectable Radiometrically 317
Apparatus and Methods Used 318
Summary of Previous Data 319
Group I. Minerals Containing Water of Crystallization 320
Group II. Minerals Containing Water of Constitution 330

INTRODUCTION.

Although investigations of infra-red absorption spectra were begun about twenty-five years ago, it was not until the first years of the present century that an attempt was made to systematize the data previously obtained, and to publish it, as well as new data, in standard wave-lengths. This was due in part to the lack of knowledge of the optical constants (which prevented the calibration) of the prisms used, and to the difficulty in operating the spectroradiometric apparatus. To some the data seemed to be of passing interest, but of no great utilitarian value. To others the data seemed useless because of the question of the purity of the material used, and because of their not recognizing that the absorption spectrum of the impurity will be weak and will be superposed upon that of the substance in question.

The early experimenters were at variance as to whether the cause of the absorption bands is an inter- or intra-molecular phenomenon. If the cause is intra-molecular, then it ought to be possible to identify certain characteristic absorption bands with specific groups of atoms, or radicals, in the compound under investigation. Now in the study of the carbon compounds, their constitution has been established by the replacement of certain constituents by organic radicals, by the preparation of a series of derivatives, by vapor density determinations, or by studying their physical properties in solution. Hence, following the example of the preceding experimenters, the writer turned to organic compounds for examples of substances having characteristic groups of atoms. Searching for further illustrations, groups of inorganic substances (*e.g.,* sulphates and nitrates) were examined. The chemical formulæ of minerals appeared to be written with such exactness that this seemed a rich field for material. But it was soon found that in mineralogy, which is essentially the chemistry of silicon compounds (see Myers's Mineralogy), it has as yet not been possible to apply any of the aforesaid methods used in organic compounds; that the constitution of many minerals has been derived indirectly from analogies with other compounds which are better understood, and that in many cases the constitutional formulæ are in doubt.

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* Extract from a paper to be published in the *Bulletin of the Bureau of Standards.*

Being familiar with the older ideas in regard to the condition of water in crystals, it seemed easy to settle the question of inter-molecular action in causing absorption bands; by investigating substances containing *"water of constitution";* but at the very beginning[1] it was found that this particular subject was in a more hopeless state of confusion than all the rest.

In the meantime, extensive investigations of all sorts of compounds proved conclusively that the important groups of elements, radicals, which are found in chemical compounds, have a definite effect upon radiant energy, especially upon low frequency, or so-called infra-red, radiation. This effect is manifested by intense absorption bands, the positions of which are characteristic of the radical or group of atoms causing these bands.

Hence, as a result of the application of these facts, it has come about that, instead of turning to chemistry and to other branches of physics to obtain evidence to explain the phenomena observed when radiant energy is passed through or is reflected from a substance, the problem is reversed and these very phenomena are now applied to explain several conspicuous and intricate questions concerning the constitution of matter, and, in particular, the question of the manner in which water, or the constituents which form water, are combined in chemical compounds.

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[1] Coblentz, *Physical Review,* 20, p. 252, 1905.

The investigation of water in minerals has been carried on at various times [2] during the past six years. The interest which Dr. Hillebrand has taken in this method of analysis has served to renew my interest in it and to further test its possibilities. After due consideration of the problem it was deemed best to renew the work by investigating opals having different amounts of water—from 3 to 8 per cent. After beginning the work it was found possible to decrease the water content of, and even to completely dehydrate, some specimens without seriously impairing their homogeneity. The material was selected from the collection in the United States National Museum. The water content was very kindly determined by Dr. Hillebrand, after which the cutting of the sections was done by the United States Geological Survey.

THE FUNCTION OF WATER IN SUBSTANCES.

The manner in which "*water of crystallization*" is held in minerals is not understood. By some it is considered to belong to the molecular structure; by others it is held that the molecules of water exist in their entirety among the other molecules, and hence belong only to the crystalline structure. It is a characteristic of water of crystallization that it is expelled from a mineral by very gentle ignition, always at a temperature far below red heat and frequently below 100° C.

In the case of *water of constitution,* the water is not supposed to exist as such in the mineral, but to result from the union of oxygen and hydrogen or from hydroxyl groups contained in the molecule. It is characteristic of this class of substances that they must be strongly heated, sometimes to a white heat, before they are decomposed and all the water is expelled.

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[2] "Water of Constitution and Water of Crystallization," Coblentz. *Physical Review,* 20, p. 252, 1905. *Physical Review,* 23, p. 125, 1906. *Bulletin, Bureau of Standards,* 2, p. 457, 1907. Jahrbuch Radioaktivität und Elektronik, 3, p. 397, 1907. *Physical Review,* 30, p. 322, 1910. Publication No. 65, Carnegie Institution of Washington, 1906.

The earlier writers held that in the case of crystalline substances the molecules of water exist in their entirety. whence the name *"water of crystallization."* "The compounds containing water of crystallization are usually denied the title of atomic compounds, ordinarily applied to combinations of two or more elements in which the constituent atoms are associated in a single molecule, under the influence of the force which has received the name of chemical affinity, and in contradistinction are termed *molecular* compounds, being regarded as combinations of two or more separate molecules, *e.g.*, $CaSO_4+2H_2O$. This, although perhaps true of many compounds containing water of crystallization, is certainly not true of all, and notably the sulphates, which are deprived of their water of crystallization by heating to a high temperature." [3] The last molecule retained with such persistency was termed *"water of constitution,"* to distinguish it from water of crystallization. In many compounds the affinity seems different for the different parts of the crystal water. For example, ordinary alum $AlK(SO_4)_2+12H_2O$ gives off five molecules of H_2O at 100°, and five molecules at 120°, while the last two molecules remain until heated to 200°. In the same manner in the sulphate of magnesium ($MgSO_4+7H_2O$), Zn, Fe, Ni, and Co six molecules of water are given off at about 130°, while the last molecule of H_2O does not pass off until heated to 200° to 300° C. Examples of *"water of constitution"* are sugar, mica, and brucite, $Mg(OH)_2$, in which the O and H atoms are not united as H_2O, and do not unite to form water until sufficient heat is applied.

Various criteria have been set up (often based upon physical tests, refraction and polarization) by experimenters to distinguish between these various forms of water, but all seem unsatisfactory. For example, the fact that in certain crystals the water passes off at one, two, or three fixed temperatures, with a supposed change in homogeneity, has been considered evidence that the water is present as a definite compound. But the absorption and reflection bands of selenite ($CaSO_4+2H_2O$) show that it is a "double salt" or "molecular compound";

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[3] Encyclopædia Britannica, 9th Ed., V, pp. 489 and 505. Graham-Otto Lehrbuch der Chemie, II, p. 173.

for the spectrum of selenite is the composite of the spectra of anhydrite, $CaSO_4$, and of water, H_2O.[4]

If selenite were a new compound, formed by the union of water and $CaSO_4$, then the (absorption and reflection) spectrum should be entirely different from that of the constituents, just as is true of mica. That some of these hypotheses are too narrow is shown by the fact that the absorption spectra of various substances such as selenite, opal, and the zeolites are identical as regards the position and intensity of the water bands. The water must therefore be present in the same manner in these two types of crystals; and since the absorption bands are identical with those of water in its free (liquid) state, it would appear that the temperature fixed point and vapor pressure tests are not a sufficient criterion for judging this question. If the water were chemically combined in selenite, then one would expect to find the absorption bands of water to be absent. It would appear just as tenable to consider the water occluded under a definite pressure, which raises its boiling point to a higher temperature. [As suggested by the writer some years ago, an investigation of the expansion (with change in temperature) of crystals containing water of crystallization, to learn whether there is a minimum such as obtains in water at 4° C., would be interesting.] Or we may liken the crystal unto a block built up of bricks and mortar. This analogy cannot extend very far, since an explanation is demanded: why in the one case the cement (water) crumbles at a definite temperature, while in other cases (zeolites) the phenomenon is progressive with rise in temperature.

It seems just as reasonable to assume that the water molecule can assume the same structure as the molecule of sulphate (or perhaps forms a film around the latter), and that the two crystallize in the same manner, thus building up a composite crystal just as is possible to grow a crystal of a mixture of alums.

That the hypothesis that water in crystals is united as a definite compound is based on a too narrow foundation is illustrated in the zeolites. They are crystalline compounds and the water is very loosely held. The water continues to be gradually expelled as the temperature is raised, and it may be replaced by other substances, such as NH_3, H_2S, or C_2H_5OH. The dehydrated crystals absorb definite quantities of these substances as a sponge absorbs water, the process being accompanied by the evolution of heat. Since the amount of water present varies continuously with the vapor pressure, it is generally concluded that the water in the zeolites is not analogous to the water of crystallization of most hydrated salts, but resembles more nearly the intermixture which occurs in solid solution. In this case the hypothesis is tenable, for amorphous substances, *e.g.*, opal, which have similar absorption spectra, are also considered solid solutions; and in both groups of minerals the absorption spectrum of the hydrated material is the composite of water and of the anhydrous substance. But the vapor pressure criterion is not sufficient to judge minerals, as may be noticed from the experiments on tremolite. Here, too, the water is expelled gradually[5] with rise in temperature, and it was considered dissolved water; but no absorption bands of water are observable. The small bands at 2.9 μ may be due to hydroxyl groups, as inferred by Penfield and Stanley[6]; for in brucite, $Mg(OH)_2$, in diaspore, AlOOH, and in Göthite, FeO(OH), the 3 μ band is very weak,[7] as is true of the band in tremolite.

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[4] *Bulletin, Bur. Standards*, 2, p. 457, 1907. Carnegie Publication No. 65, pp. 18, 77, and 79.

Turning from the crystals (*e.g.*, sulphate) which give off their water at one or more fixed temperatures to the zeolites, which are also crystalline substances, it is found, as mentioned on a previous page, that in the latter group of minerals the water is given off gradually between 100° and 400°. To explain this phenomenon it is supposed that the water is not chemically combined, but is present as solid solution. On this hypothesis the water should be present as such, and should give the absorption bands of water. As a matter of fact, as already mentioned, the zeolites do show the absorption bands of water; but so do the sulphates and other substances in which the water is expelled at a fixed temperature, indicating the sameness of the water in both groups. It is not clear to the writer why, if in some substances the water may be expelled at one fixed temperature and in another substance at several fixed temperatures, it is not possible to have still other crystalline structures from which the water may be expelled at all temperature gradations, and yet have the water present in the same condition in all of them, as indicated by the radiometric tests.

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[5] Allen and Clement, *Amer. Jour. Sci.*, 26, p. 101, 1908.

[6] Penfield and Stanley, *Amer. Jour. Sci.*, 23, p. 23, 1907.

[7] Publication No. 65, Carnegie Institution of Washington. *Bulletin Bur. Standards*, 2, p. 466, 1907.

THE CRITERION USED IN THE PRESENT METHOD OF ANALYSIS.

The criterion used in the present investigation for judging the condition of water in compounds is based upon the evidence deduced from extensive experimental data which shows that the absorption spectrum of a compound is *not* the composite of the absorption bands of the constituent elements. In this case the " physical molecule " has been changed. On the other hand, if the molecules (or the groups of atoms which cause the characteristic absorption bands) undergo no physical change when they combine to form a crystal (*e.g.*, selenite, $CaSO_4+2H_2O$), or when they enter into solution, then the absorption spectrum of the resultant combination will be the composite of the absorption bands of the constituents. Now this is the proposition that conflicts with some of the notions concerning definite chemical compounds. From the fact that there is a certain heat of hydration manifested in the formation of a crystalline substance (*e.g.*, hydrous sulphates), it is inferred that there is a new compound formed, when as a matter of fact the radiometric test shows that the water and the sulphate bands are just the same in magnitude and in position as they were before the constituents were united.

In judging the condition of water in minerals the main difficulty is in using substances which in the anhydrous state have no large absorption bands near the bands characteristic of water in its free (liquid) state. An excellent example is found in selenite ($CaSO_4+2H_2O$), which has an unusually large absorption band at 4.6 μ. This seemed to throw doubt upon the adequacy of the radiometric test until after the examination of anhydrite ($CaSO_4$) and other anhydrous sulphates, when it was shown that this large absorption band is characteristic of the sulphates. In the same manner the presence of OH groups in cane sugar confuses matters at 3 μ. So that the probability of cane sugar having a molecule of water of crystallization is based upon the evidence deduced from the presence of absorption bands at 1.5 μ and 4.75 μ, which coincide with the water bands at these points. The evidence not being very strong in this case, the writer has never laid much stress upon it, in spite of the great similarity of the spectrum to that of other sugars having H_2O. In all the other examples previously described, the most superficial examination shows that the absorption bands of water in the various minerals are identical in magnitude and in position with those found in water in its free (liquid) state. Hence, in the present investigation, the criterion for distinguishing water of crystallization from water of constitution is the presence of absorption bands at 1.5, 2, 3, 4.75, and 6 μ, which is the location of the absorption bands of water. If there are no other absorption bands near by, then the intensity of these bands will be found similar to those of water, *viz.,* the bands at 1.5, 2, and 4.75 will be weak, while the bands at 3 μ and 6 μ will be very strong. Hydroxyl groups cause an absorption band at 3 μ, hence not distinguishable when present with water. Furthermore, the evidence for OH groups is not so clear-cut and definite as is found in water of crystallization. The intensity of the band seems to depend upon the activity of the OH group. For example, of the various hydroxides studied, the alcohols, etc., have a sharply defined band at 3 μ, while in brucite, $Mg(OH_2)_2$, and in several other minerals, the band at 3 μ is almost, if not entirely, wanting. In the alcohols, etc., the OH is more active, since it is replaceable by a metal (more acid) than the OH in brucite, which is not replaceable (more basic). Whether this is the true explanation of the phenomenon remains undetermined; and since the question of OH groups is of secondary importance in the present work, it need not be given further attention at present.

In passing it is of interest to note that substances containing the COOH or the $C = O$ group have a very marked absorption band in the region of 5.8 to 5.9 μ. Silicates, as well as quartz, have a very small absorption band in the region of 2.9 μ, which is barely noticeable in the thin sections of minerals examined. Since the band is so weak, there is no danger of confusing it with the strong water band at 3 μ in opals.

In contrast with the other criteria, the radiometric test of the condition of water in minerals gives far more consistent results in classifying certain minerals. It is to be noticed, however, that this method of analysis shows no distinction between "*water of crystallization*" and "*dissolved water*" or "*water of solid solution.*"

In its behavior toward radiant energy, the molecule of water in crystals and in solid solution is identical with water in its free (liquid) state. This is, of course, in conflict with the commonly accepted notions concerning water of crystallization and water of solid solution; but it seems to be the only logical interpretation of the data obtained by the present method.

The main difficulty in this investigation is in obtaining substances which in the anhydrous state are free from absorption bands. This is practically impossible, since all substances have characteristic absorption spectra. Hence the best that one can do is to investigate various substances. Some give inconclusive evidence in one region of the spectrum (*e.g.*, cane sugar at 3 μ), while others confuse matters further in the infra-red (*e.g.*, the sulphates at 4.55 μ). Considered as a whole, however, the evidence is complete and convincing.

THE LEAST THICKNESS OF WATER DETECTABLE RADIOMETRICALLY.

This is about the first question asked in connection with the methods used in the present investigation.

On a subsequent page it will be shown that a given layer of water vapor is far more transparent than the same column when condensed into a liquid film; although the large absorption bands are found in both the liquid and in the vapor phase, the only difference being that of intensity. The film of water which is found on rock salt (prisms) does not cause absorption bands.

Whether the absorption bands of water are absent in substances which are more hydroscopic than rock salt (or in rock salt itself when exposed to very humid air) has not been determined. Furthermore, it must be shown that such a film of water is continuous.

It will be shown presently (see Figs. 6 and 7) that after dehydrating a certain sample of opal it absorbed water at the rate of about .06 per cent. (see Fig. 7B) per day. The various transmission curves are so widely separated that an increase in the water content amounting to one-third to one-fourth this value (or .02 per cent.) could easily have been detected. The thickness of the section of opal was .105 mm.; and, if .02 per cent. of it was water, the equivalent layer of water, if concentrated into a liquid film, would be about 3/100,000 mm. in thickness.

APPARATUS AND METHODS USED.

The apparatus used in the present investigation is essentially the same as used in previous work. The spectrum was produced by means of a 60° fluorite prism mounted on a spectrometer made of silvered mirrors 50 cm. in focal length. The spectrum was explored by means of a very sensitive vacuum bolometer, which is now being used in all radiation work requiring high precision. The period of the auxiliary galvanometer was only 4 seconds, which means a great saving in time when one considers that, in some of the earlier work, 1 to 1.5 minutes were required to make a single observation. The spectrometer slit and the width of the bolometer were 0.6 mm. wide or 4′ arc. A Nernst glower was used as a source of energy. An image of the glower was projected upon the spectrometer slit by means of a 15 cm. focal length silvered mirror. The crystal section was mounted in a holder directly in front of the spectrometer slit. The methods of observation consisted in (1) noting the galvanometer deflection when the crystal section was in the path of the light from the glower, and (2) noting the galvanometer deflection when the crystal section was not before the spectrometer slit. The ratio of (1)÷(2) gives the transmission in any given part of the spectrum; and it is simply a matter of setting the bolometer in different parts of the spectrum and noting the two galvanometer deflections. The method is analogous to spectrophotometric measurements, the bolometer being substituted for the eye. An accuracy of one part in 200 to 400 is easily attainable, which is more precise than is required.

The mineral sections were ground thin, but not highly polished. The size of the specimens was about 8 x 15 mm. They were mounted upon thick cardboard having rectangular openings cut therein. In this manner no light reached the spectrometer slit, except that which passed through the mineral section.

For further details in regard to apparatus and methods of observation the reader is referred to previous investigations of a similar nature.[8]

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[8] *Physical Review,* 16, p. 35, 1903. Publication, Carnegie Institution, No. 35, 1905; No. 97, 1908. *Bulletin Bur. Standards,* 4, p. 392, 1907.

SUMMARY OF PREVIOUS DATA.

In previous investigations of at least thirty-four substances, said to contain "water of crystallization," the one exception (aside from tremolite, which is included in the present paper) to the rule that such substances show the absorption bands of water was brucine ($C_{23}H_{26}N_2O_4+4H_2O$), which is an alkaloid having a complicated and unknown structure. An extensive examination of this compound failed to reveal any absorption bands of water. The transmission curve[9] has sharp bands at 1.7, 3.43, 6.86, and 7.3 μ which are to be found in all substances containing CH_2 and CH_3 groups. It has also a very large band at 5.95 μ (and 8.3 μ) which is to be found in all substances containing the $C=O$ group. It is quite transparent throughout the infra-red. It is supposed to contain 16 per cent. of crystal water, which would be sufficient to cause a far greater opacity than observed radiometrically.

The list of minerals containing water of constitution included about a dozen samples of hydroxides, OH groups. As stated elsewhere, the absorption band of OH groups so characteristic of alcohols at 3 μ is often very weak, and sometimes it is entirely unresolved by the spectroscope. In serpentine there is a band at 3 μ which is very strong, and confirms the view that there are hydroxyl groups present in this mineral. The radiometric analysis also confirmed the view[10] that there are no hydroxyl groups in talc, in which there is not even a trace of an absorption band at 3 μ.

The one exception to the other methods of classifying the twenty-eight substances examined, containing water of constitution, is cane sugar, which is not supposed to have water of crystallization. As mentioned on a previous page, the evidence is not very strong; but there is sufficient similarity between the transmission spectrum of cane sugar and of other sugars having water of crystallization (there is no similarity with fructose, which has no crystal water) to suggest the presence of a molecule of water of crystallization.

It seems rather remarkable that out of a sum total of more than sixty substances examined radiometrically only two (perhaps only one) were found which did not agree with the other classification into water of crystallization and water of constitution.

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[9] Publication No. 65, p. 40, Carnegie Institution of Washington.

[10] Clarke and Schneider, *Amer. Jour. Sci.*, 40, p. 308, 1890.

GROUP I.—MINERALS CONTAINING WATER OF CRYSTALLIZATION.

Under this heading are described the characteristics of several crystalline and amorphous substances containing water. For, as already mentioned, the radiometric test finds no distinction between water of crystallization, absorbed water, or water in solid solution.

Water (H_2O).—In order to appreciate fully the significance of the data to be presented on minerals, it is necessary to describe the characteristics of water when examined in the liquid and in the vapor state. All observers [11] agree in their location of large absorption bands of water at the approximate wave-lengths 1.5, 2, 3, 4.75, and 6 μ. All have found that water is extremely opaque to the deep infra-red radiation, so that the film had to be reduced to a few thousandths of a millimeter in thickness in order to be able to study it at all.

In fact, of all the substances examined, which included all the great groups of chemically related compounds, water stands unique in having a spectrum of numerous narrow absorption bands, which can be resolved only when the substance is reduced to a highly attenuated vapor. In the liquid state these groups of small bands coalesce into large bands, as indicated in Fig. 1. It is, of course, well known that a very thick layer of water is required to produce absorption in the visible spectrum.[12] The same is true for the infra-red region out to .933 μ (the "P" band in Fig. 2), but beyond this point the "general absorption" increases very rapidly, so that a layer of water 1 cm. in thickness absorbs all frequencies beyond 1.4 μ, and a layer .5 mm. in thickness causes complete opacity beyond 2 μ. The absorption of water for heat waves longer than 5 μ is so much greater than at 2 μ that a layer only .1 mm. in thickness causes complete opacity beyond 5 μ. Beyond 8 μ (to 50+ μ) water is quite transparent, having no large absorption bands which would be useful in investigating the present problem.

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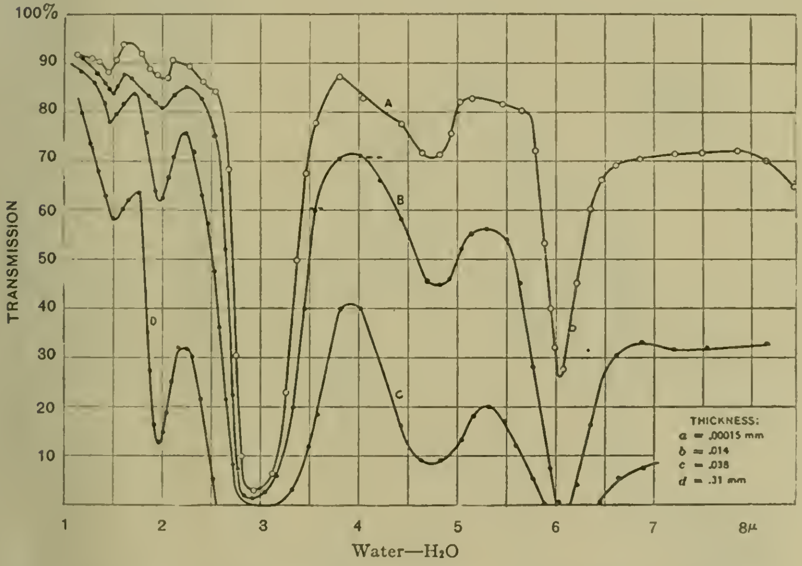
[11] Julius, Verhandl. Königl. Akad. Amsterdam. Deel I, No. 1, 1892. Paschen, *Ann. der Phys.* (3), 53, p. 334, 1894. Aschkinass, *Ann. der Phys.* (3), 55, p. 406, 1905.

[12] Abney and Festing, *Phil. Trans.*, 172, p. 887, 1882. Kayser, Spectroscopie, Vols. 2 and 5.

The transmission curves of various thicknesses of water ($a = .00015$ mm.; $b = .014$ mm.; $c = .038$ mm.; $d = .31$ mm.) are given in Fig. 1. The cell, containing water, was made of two large, clear fluorite plates separated by tin foil. The various thicknesses were obtained by varying the number of layers of tin foil. For curve *a*, the thinnest obtainable platinum, used in making bolometers, was inserted between the fluorite plates. The thickness of the platinum was computed from the electrical resistance and the surface dimensions of a bolometer strip. These curves show the great opacity of water at 6 μ as compared with the region of 1.5 and 2 μ.

FIG. 1.



Angström[13] has shown that water vapor is more transparent than the liquid phase, when in such layers that the thickness is inversely proportional to the density. A familiar example is atmospheric water vapor, which transmits the sun's radiation[14] to 11 μ, while a layer of water about two centimeters thick, which is equivalent to the water vapor in the earth's atmosphere (see Arrhenius Lehrb. der Kosmischen Physik), absorbs everything beyond 1.2 μ. The complexity of the absorption bands at 1.45 μ and at 2 μ, in Fig. 1, is shown in the spectrobolographic curves[15] made at the Astrophysical Observatory. These curves are reproduced in Fig. 2. The upper curve, for Feb. 19, 1903, was made when there was but small water-vapor absorption. The lower curve, for Sept. 14, 1903, was made when the humidity was high and hence there was great water-vapor absorption. The rapid variation in intensity of the absorption bands is analogous to the observations in Fig. 1. A further

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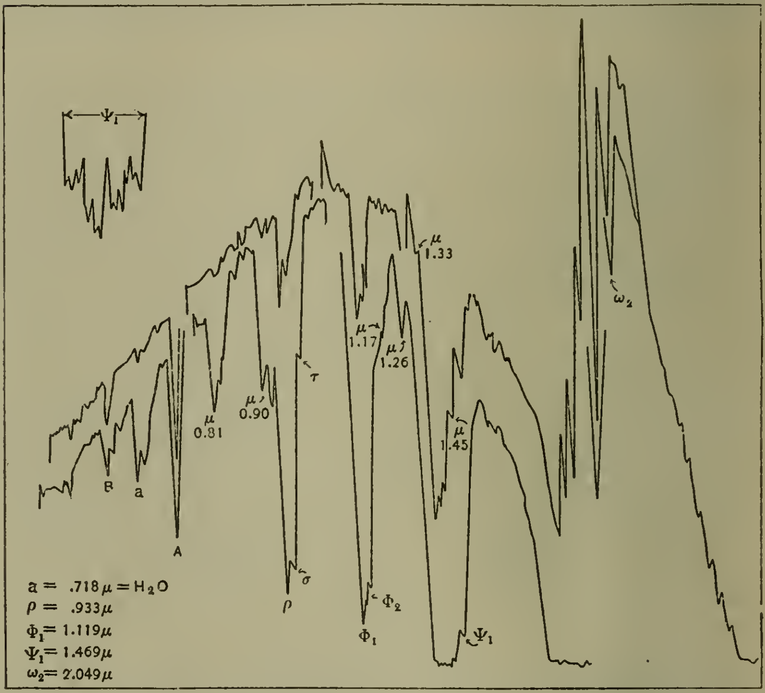
[13] Angström, *Ann. der Phys.* (3), 39, p. 267, 1890; (4) 6, p. 163, 1901.

[14] Langley, Nat. Acad. Sci., 4, part 2, p. 197. Discussion in Carnegie Publication No. 97, p. 143.

Fig. 2.



Bolographic energy curves of the solar spectrum of a 60° glass prism.

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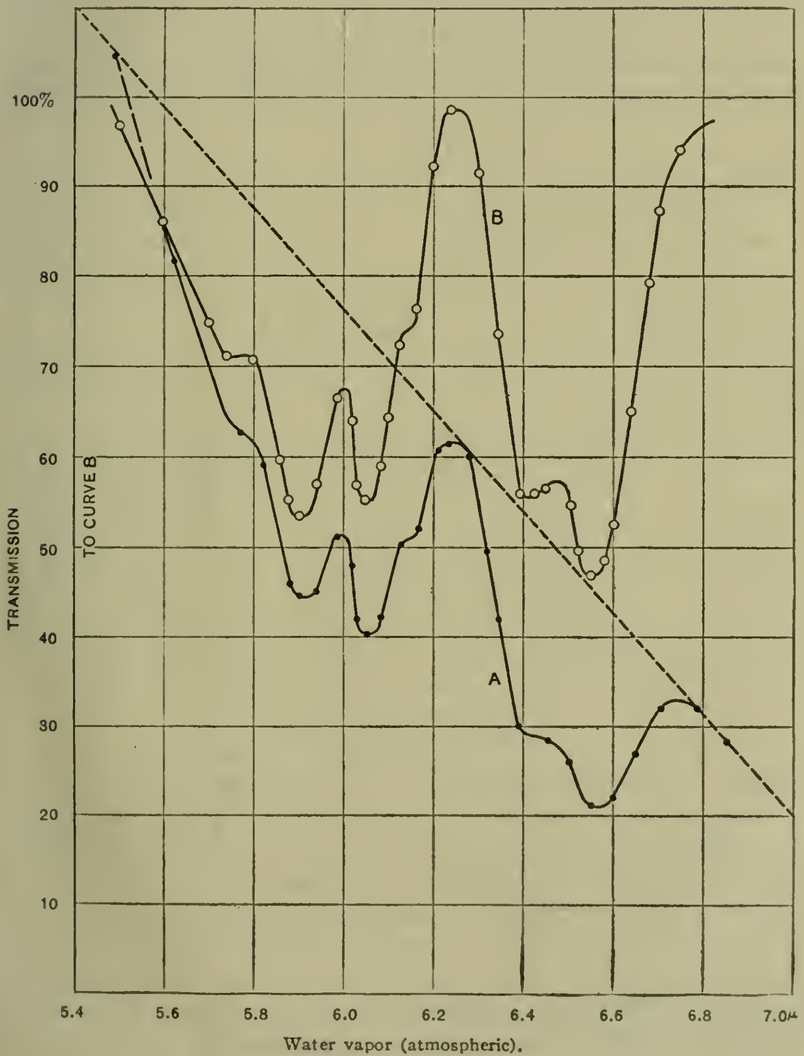
[15] Fowle, Smithsonian Misc. Coll., Vol. 47, No. 1468, 1904.

illustration of the complexity of the water bands is given in Fig. 3, which relates to the band at 6 μ in Fig. 1. Curve *a*,

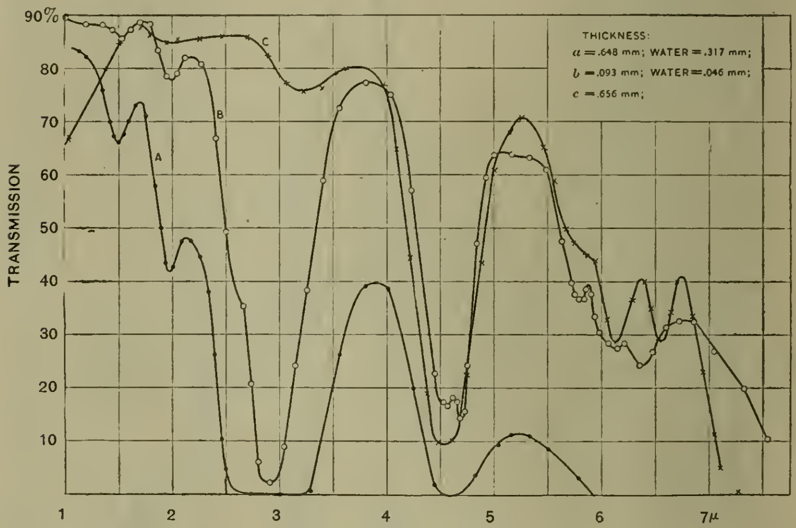
FIG. 3.



Water vapor (atmospheric).

Fig. 3, was obtained by placing a Nernst glower at a distance of 4.2 meters from the spectrobolometer and projecting an image of the glower upon the spectrometer slit by means of a large concave mirror. The spectral energy curve was then observed in the usual manner. When plotted to scale as shown in curve *a,* Fig. 3, the energy curve shows numerous indentations. The dotted line represents roughly the spectral energy curve of the glower if there were no absorption bands. By taking the ratio of the ordinates of the continuous part of curve *a* to the dotted curve at various wave-lengths, curve *b* is obtained. The latter represents very closely the transmission of 4.2 meters of air, which contains a layer of precipitable water equal to .02 mm. in thickness. The water content was derived from the relative humidity (= 25 per cent.; room temperature = 21.7°) and the amount of water vapor per cubic meter. It is to be noticed that the 6 μ band which shows complete opacity for a similar layer of liquid, curve *b,* Fig. 1, is resolved into at least six bands with maxima at 5.75, 5.91, 6.05, 6.15, 6.41, and 6.56 μ. The short air column used, 4.2 m., was not sufficient to show the absorption bands of water vapor at 3 μ.

Fig. 4.



Selenite—$CaSO_4+2H_2O$
Anhydrite—$CaSO_4$ (curve C)

Anhydrite ($CaSO_4$).—The substance examined was a cleavage piece, split parallel to the *c* axis; thickness = .656 mm.

The transmission curve, *c*, Fig. 4, of this mineral shows small absorption bands at 3.75, 5.75, 6.15, and 6.55 μ; a very large band, at 4.55 μ, is due to the SO_3 ion, and is characteristic of sulphates. This mineral was investigated previously, and is included here to illustrate the great difference in the opacity of the hydrous and the anhydrous mineral (see curves *a* and *c*, which have practically the same thickness).

Selenite ($CaSO_4+2H_2O$).—The sections examined were cleavage pieces split parallel to the *b* axis; the thicknesses being $a = .648$ mm., $b = .093$ mm. respectively (Fig. 4). Since twenty-one per cent. of selenite is water, the thickness of the water, if free, would be 48.8 per cent. (sp. gr. of selenite is 2.33; $2.33 \times 21 = 48.8$) of the thickness of the specimen, or $a = .317$ mm. and $b = .046$ mm. of water.

Of all the minerals investigated, containing water of crystallization, this and the following one are the most conspicuous for demonstrating the effect of water upon the absorption spectrum of substances. The absorption bands of water at 1.5, 2.0, 3, 4.75, 6.0, and 6.5 μ are very conspicuous in spite of the anhydrite bands which confuse matters at 6 μ. It is to be noticed that a layer of water in its free (liquid) state, curve *d*, Fig. 1, is far more opaque than an equivalent layer, curve *a*, Fig. 4, when held in a crystal. This is evident from the fact that the .31 mm. layer of water is entirely opaque beyond 2.5 μ. In fact, the transmission spectrum of selenite indicates the presence of water in more nearly the vapor state, in which it is possible to resolve the large bands into smaller ones (see Fig. 3). This change in density of water in the process of crystallization involves energy changes which may require consideration in connection with the question of thermal equilibrium in dehydration.

In previous investigations[16] partially and completely dehydrated, also rehydrated, samples of selenite were examined, to which reference must be made in order to fully appreciate the bearing of this data upon the question of water of crystallization.

Opal (SiO_2+xH_2O).—Samples of opal and quartz have been examined previously.[16] Quartz has small absorption bands at 2.9, 4.35, 5.02, 5.3, 6.0, 6.26, and 6.65 μ. The band at 2.9 μ is barely observable in a section .1 mm. in thickness. Curve *c*, Fig. 5, gives the transmission of a section 1.435 mm. in thickness, cut perpendicular to the optic axis. The maximum lies at

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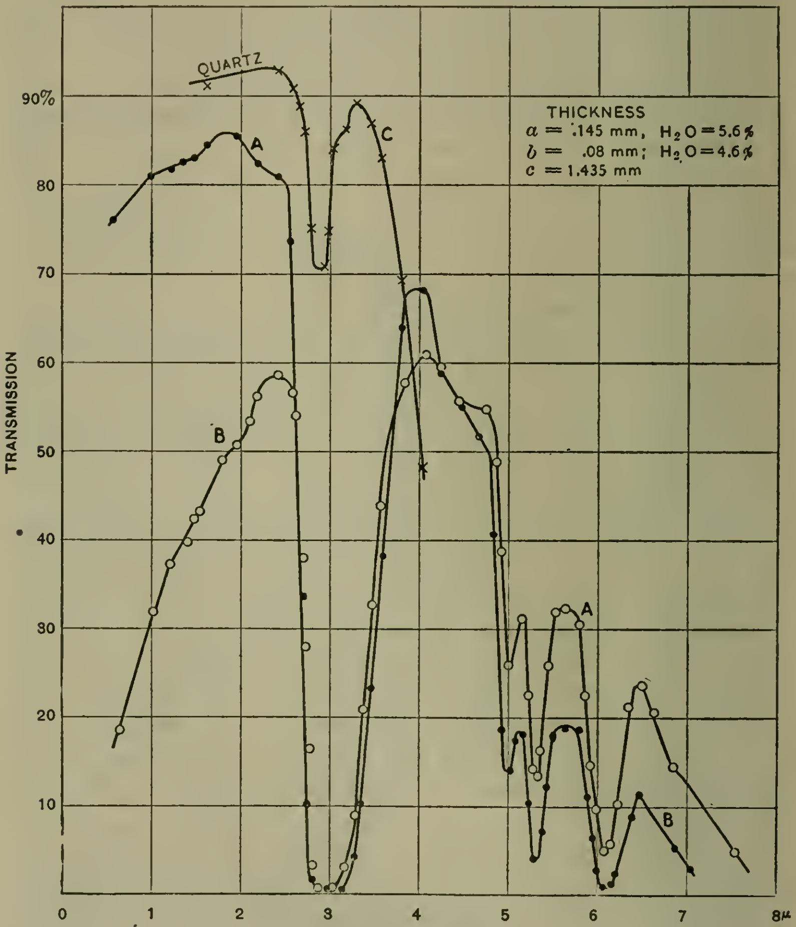
[16] *Bulletin, Bur. Standards*, 2, p. 457, 1907. Carnegie Publication No. 65.

FIG. 5.



Opal—SiO_2 + χ H_2O
Quartz—SiO_2

2.88 μ. This absorption band is so weak that it cannot interfere with the water band at 3 μ. The bands at 6 and at 6.26 μ form a composite with the water band at 6 μ, of which the maximum appears at 6.1 μ. The group of atoms in quartz is very strong and maintains its characteristics, more or less sharply defined, in the various silicates investigated.

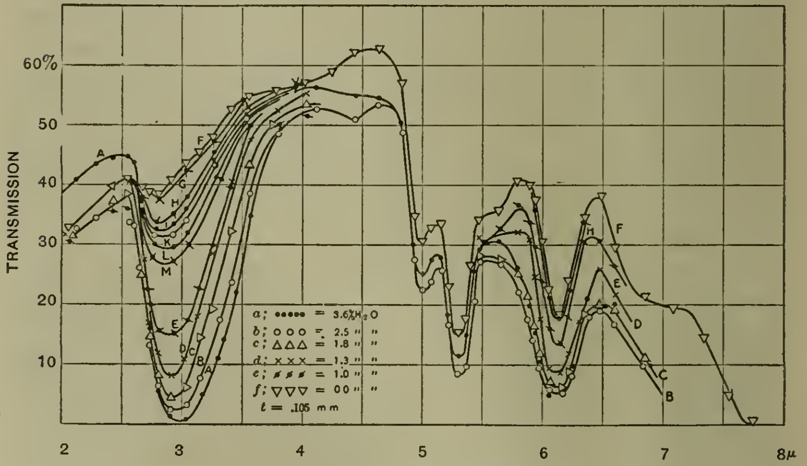
Opal (amorphous quartz) contains variable proportions (2 to 30 per cent.) of water. It shows no traces of crystallization. Opal is considered a solid solution, for the water contained is a function of the vapor pressure.

The transmission curve of opal has the general outline[16] of the curve for water and contains the bands of water at 1.5, 2, 3, 4.75, and 6 μ. The latter is complex, as mentioned above.

For the present work the samples of opal were not perfectly transparent, which caused a scattering of the rays shorter than 2.5 μ. In Fig. 5, curve *a* gives the transmission of a sample of opal (from Queretario, Mexico) .145 mm. in thickness, and containing 5.6 per cent. of water. In transmitted light it showed a slightly milky white color which scatters the light to 2 μ. Curve *b* gives the transmission of a whitish, semi-translucent sample (from Silesia) .08 mm. in thickness and containing 4.6 per cent. of water. The equivalent layer of water for curve *a* is, t = .018 mm., and for curve *b* it is, t = .0077 mm. The rapid decrease in the general transmission beyond 4 μ is due to the great opacity of quartz beyond 3 μ.

In Fig. 6 is given, curve *a*, the transmission of a semi-translucent sample of opal, t = .105 mm. in thickness, originally containing 3.6 per cent. of water. The equivalent layer of water (sp. gr. of opal = 2.1) is .0079 mm. It was found possible to dehydrate the specimen without seriously increasing the inhomogeneity, as illustrated at 2 to 3 μ. In order to dehydrate the specimen, it was necessary to dismount the section from its cardboard support and place it in a porcelain tube, which was then heated with a Bunsen flame or blast lamp. The specimen was weighed before and after heating, and knowing the water content before heating it was possible to compute from the loss in weight the water remaining after heating. For example: starting with the section weighing 32.037 mg., the loss in weight was .360 mg. The original water content was 3.6 per cent., from which it was computed that for curve *b*, Fig. 6, the water content was 2.5 per cent. The weighings were made by Mr. W. C. Bishop, whose long experience in such work insured both speed and high accuracy. The weighings were made on an assay balance taking a maximum load of 1 gram. The working sensitivity was 1 mg. = 10 divisions; probable error of a single weighing .002 to .005 mg. It was found that the weighings became constant in less than ten minutes after dehydration. It will be shown presently that this specimen absorbed about .06 per cent. of water per day. Since the weighings were completed and the specimen was remounted within 15 minutes after dehydration, and since the observations on the absorption band at 3 μ were completed within 45 minutes after heating the specimen, this question of reabsorption (so frequently asked by all comers) needs no further consideration. Curves *c, d,* and *e* were obtained in the same manner as curve *b*. Each time the section was dismounted there was a slight loss due to breakage, so that after obtaining curve *e* the specimen was placed in a platinum receptacle and heated to a bright red (700°) for one hour. It was then mounted permanently upon the cardboard support and on examination gave curve *f*, Fig. 6. The small band at 2.9 μ remains; but whether it is due entirely to SiO_2, or whether it still represents a trace of water, remains undetermined. After standing over night it reabsorbed moisture, giving curve *g*. Two days thereafter the transmission had fallen to curve *h*. This examination of the reabsorption of water was continued for seventeen days after dehydration, the relative humidity of the

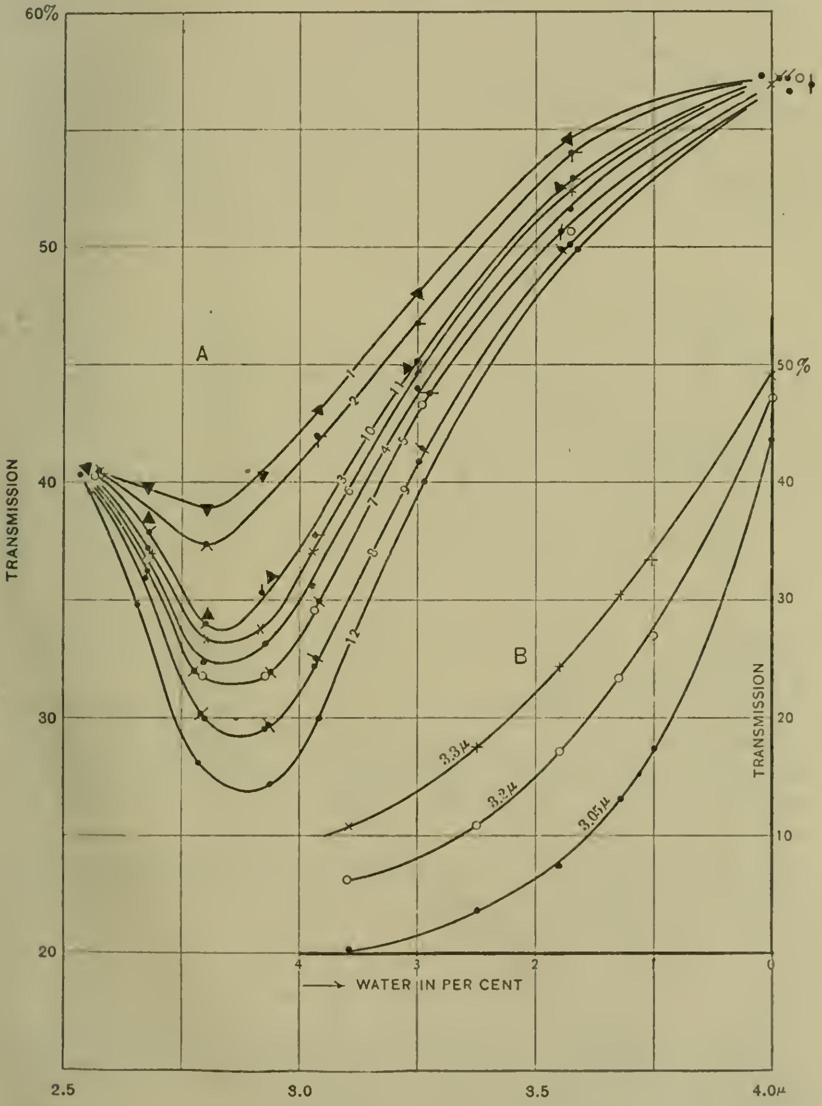
Fig. 6.



Opal in various stages of dehydration.

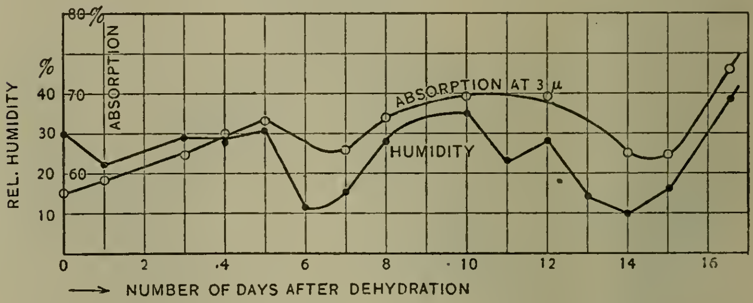
laboratory being determined daily by means of a ventilated hygrometer. The daily variation of the absorption band at 3 μ

Fig. 7.



is shown in Fig. 7A, which represents curves *f*, *g*, . . . *m*, Fig. 6, on a different scale. The numbers attached to the various curves indicate the order in which they were observed. In Fig. 7B are given several isochromatic transmission curves, obtained from curves *a, b, c, d,* and *e* of Fig. 6. From these curves it is possible to obtain a rough estimate of the water content represented in the curves 2 to 12, Fig. 7A. The disappearance of the water band at 6.1 μ is not so marked as at 3 μ; but it is evident that, in making allowance for variation in homogeneity, this part of the curves, Fig. 6, cannot be superposed. The bands at 5.0 μ and 5.3 μ are due entirely to silica, and there would be no difficulty in superposing them. It will, of course, be understood that in the frequent remounting of this specimen it was not possible to obtain the transmission of exactly the same part of the section each time.

FIG. 8.



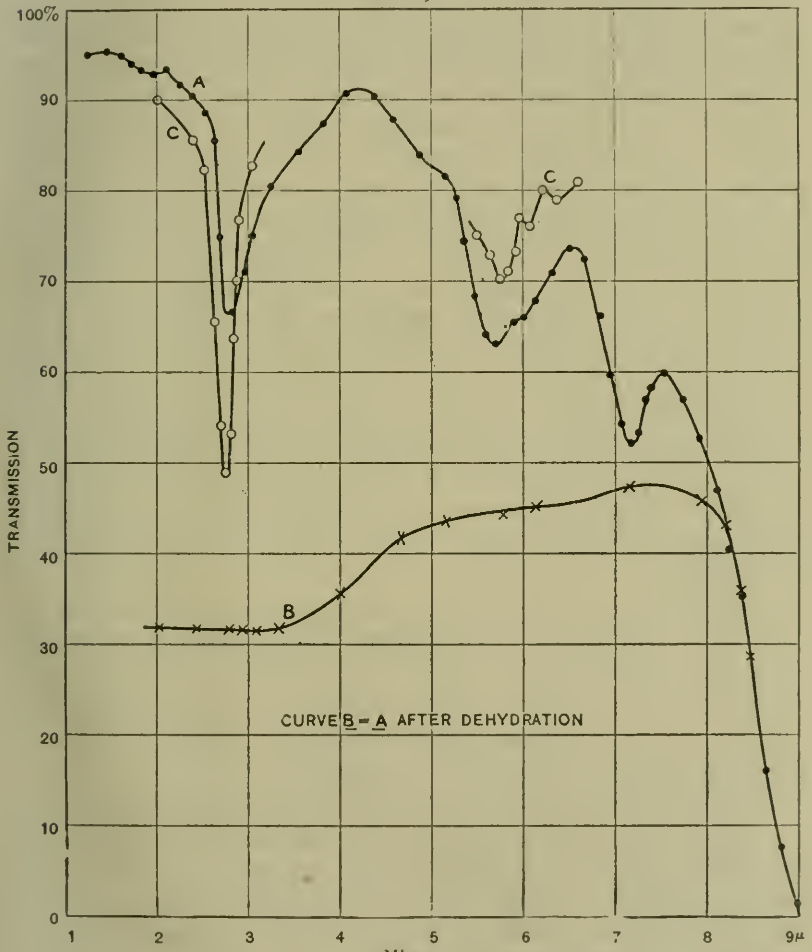
During the examination of the rehydration of this sample of opal there were two cold periods when the relative humidity decreased to ten per cent. It was then found that the opal became dehydrated. This is illustrated by the two depressions in the curves in Fig. 8, which show the variation of water in opal (as measured by the variation in the absorption) with variation of atmospheric humidity. There is a lag of about half a day in the hydration curve.

GROUP II.—MINERALS CONTAINING WATER OF CONSTITUTION.

Under this heading are collected the minerals which contain water, but which do not show the characteristic absorption bands found in water in its free (liquid) state.

Muscovite Mica ($H_2KAl_3(SiO_4)_3$).—The transmission spectra are given in Fig. 9. Curve *a* was obtained with a rock salt prism, while curves *b* and *c* were observed with a fluorite prism. The thickness was .04 mm. Curve *b* shows the transmission of the specimen after dehydration. The absorption bands are common to silicates; and none are in common with

FIG. 9.



Mica.

those of water. The band of selective reflection beyond 9 μ does not seem to be affected by the constitutional water, as should be the case, since it is known that these bands are due to the SiO radical. The other bands disappear on dehydration, as they should, since on dehydration only the constituent oxides remain. The layer of mica is too thin and the inhomogeneity is too great to show the weak absorption band of silica at 2.9 μ. A more complete list of minerals containing water of crystallization is given in previous communications [16] on this subject.

Tremolite ($CaMg(SiO_3)_4$).—The transmission of a section of this mineral, 0.23 mm. in thickness, was described in a previous paper.[17] The section was kindly prepared by Dr. Allen, of the Geophysical Laboratory, who found two per cent. of water, which appears to be present in solid solution. The section of tremolite was of sufficient thickness to insure detecting the water, provided its absorption is as great as in the liquid phase. The equivalent layer of water was .0138 mm., but no water bands could be detected. It is evident from this and from the transmission of a layer of water .014 mm. in thickness (Fig. 1, *b*) that the water in tremolite is in an entirely different condition from that which obtains in the crystals and in the solid solutions previously investigated by this method of analysis. Thinking that further information would be disclosed, the investigation of this interesting mineral was undertaken anew, using samples of the same specimen previously examined.

In the earlier work [18] it was found that a sample of amphibole (probably hornblende) showed no traces of water, the small absorption band at 2.9 μ being similar to that found in feldspars.

The sample of tremolite used in the present examination was .095 mm. in thickness. The small absorption bands at 2.9 and 3.2 μ are, therefore, not so sharp as found in the .23 mm. sample previously examined. On the assumption that two per cent. of water was present, the equivalent layer of water (sp. gr. of tremolite is 3) is .0057 mm. in thickness.

The transmission of this sample before dehydration is given in curve *a*, Fig. 10. Curve *b* represents the transmission after heating the specimen for half an hour at 200° in an atmosphere of dry hydrogen. The curve is superposable upon curve *a*. Curve *c* gives the transmission after heating the specimen in an electrically heated porcelain tube furnace at 500° for five hours. In this case the absorption band at 2.9 μ is practically destroyed.

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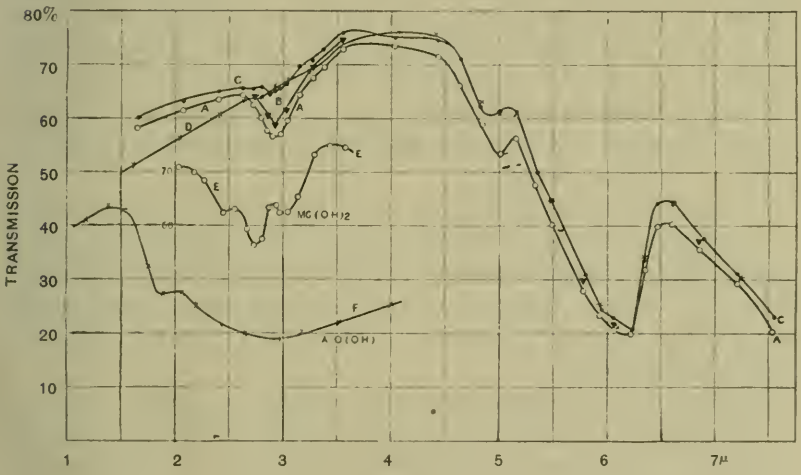
[17] *Physical Review*, 30, p. 326, 1910.

[18] Carnegie Publication No. 65, p. 64.

Curve *d* gives the transmission after heating the specimen in the electric furnace at 925° for five hours. The transmission curve is identical with curve *c*, showing that most of the chemical change was brought about at 500°.

In the dehydration the specimen became slightly inhomogeneous, which caused a scattering of the radiation to 3 μ. The band at 2.9 μ has entirely disappeared, showing that it belonged to the compound that existed before dehydration. The bands at 5 and 6 μ have undergone no change. They belong to anhydrous silicates; and the general outline of the transmission curve is not unlike that of the feldspars.[18]

FIG. 10.



Tremolite.

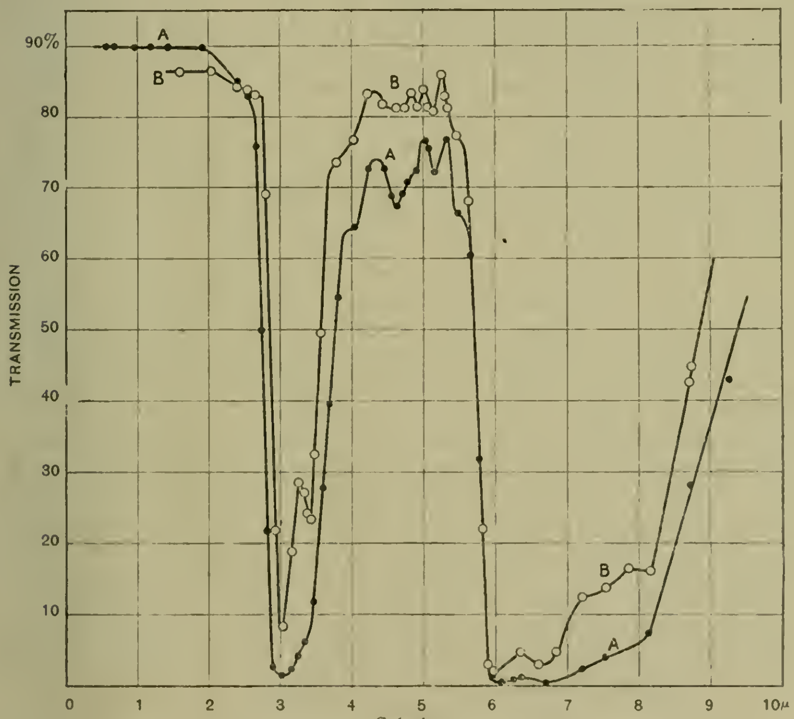
In Fig. 10 are also given the transmission curve of brucite, $Mg(OH)_2$, and of diaspore, AlO(OH). The brucite curve shows a complex region of absorption bands at 2.5, 2.75, and 3.0 μ. The 3 μ band is found in substances having OH groups. In diaspore the absorption is very complex and the individual bands, which no doubt exist, are not resolved. Bauxite, $Al_2O(OH)_4$, and Göthite, FeO(OH), also have wide bands at 3 μ.

The chemical composition of amphiboles, of which tremolite is a species, does not appear to be definitely known, some[5] arriving at the conclusion that the water is present as "dissolved water," while others[6] considered the water to be present as hydroxyl groups combined with Al_2O_3 and Fe_2O_3. From the present data it is evident that the water in tremolite is not present in the same condition as in other substances containing water in solid solution or dissolved water. Attention has already been called to the fact that in selenite the density of water is much less than in the free state, so that a layer of water equivalent to .31 mm. transmits radiation to 6 μ, while a film of water .31 mm. in thickness is completely opaque beyond 2.5 μ. The "density" of water in opal is far less than in selenite, but its opacity is of the same order of magnitude. Again, if we consider opal, having three per cent. of water (sp. gr. = 2), we find that six per cent. of the thickness of the section is water and the absorption bands of water are very prominent, while in tremolite (sp. gr. 3), in which the thickness of the water layer is also six per cent., the absorption bands of water are entirely lacking.

From the present data it appears that in tremolite the water is constitutional, with possible OH groups, the small band at 2.95 μ being complex, as in the other hydroxides just cited. This is, of course, contrary to the vapor-pressure experiments; but it is the most satisfactory conclusion to be drawn from the present experiments.

Gelatin.—This substance belongs to the albumins, of which the chemical constitution is unknown. They contain C, H, O, N, and S. The present examination was made to determine the variation in intensity of the water bands with variation in the water content. The film was .025 mm. in thickness, and it was perfectly clear. Curve *a*, Fig. 11, gives the transmission curve before dehydration, and curve *b* gives the transmission after partial dehydration, the film being tinged a faint light brown. The peculiarity of these curves is the absence of absorption bands at 1.5 and 2 μ. The general appearance of the transmission curve is entirely unlike that of water and of substances containing water. The absorption bands are sharp and narrow, as usually found in carbohydrates. In fact, the whole curve appears as though the water were present as "water of constitution," the sharp band at 3 μ being due to OH groups. The 3.4 and 6.8 and 7.3 μ bands are characteristic of substances rich in CH_2 and CH_3 groups. The very sharply banded region of great opacity at 6 to 8 μ is characteristic of carbohydrates containing NO_2 groups. There are absorption bands at 2.4, 3.0, 3.43, 4.0, 4.6, 4.9, 5.15, 5.5, 6.0, 6.8, 7.3, and 8.1 μ. This conclusion that the water in gelatin is constitutional, instead of being held as is water in a sponge, is in agreement with the notions held by several chemists with whom the writer has discussed this data. Furthermore, the conclusion, arrived at four or five years ago, that cane sugar contains water of crystallization (or water present in a similar manner, whatever name we choose to give it) is no longer so antagonistic to the views held as to the condition of the water present in this sugar.

FIG. 11.



Gelatin.

In conclusion, it may be added that this method of analysis is entirely different from any of the others heretofore employed. While nothing very marked can be claimed for it at present, it has served the purpose of giving us a clearer understanding of the rôle of water in substances, and of indicating errors in the conclusions arrived at by other methods.

Electrical and Mechanical Properties of Alloys of the Noble Metals. W. GEIBEL. (*Z. Anorg. Chem.*, lxx, 240.)—*Palladium-silver alloys.*—The existence of a continuous series of mixed crystals is confirmed and the curves expressing their mechanical and electrical properties correspond to those of the *palladium-gold* series. The minima for electrical conductivity, temperature coefficient, and thermo-electro-motive force, occur at 40 at. per cent. silver, and the maximum tensile strength at 50 at. per cent. silver. The temperature coefficient is extremely small at the minimum. The negative value of the thermo-electro-motive force of palladium towards platinum is augmented by the addition of silver. All the alloys can be drawn to wire, but they occlude gases too readily for practical purposes. *Palladium-platinum alloys.*—Electrical and mechanical properties show that this series also consists of a series of mixed crystals. The tensile strength and thermo-electric-motive force at 1200° C. reach maxima at about 45 at. per cent. platinum, while the electric conductivity and temperature coefficient reach their lowest values at this composition. It is difficult to draw wires with this series, and the alloys are of little practical value. The maximum hardness is with 45 at. per cent. platinum. The values for thermo-electric-motive force are positive towards palladium and with 10 at. per cent. platinum they are also positive towards platinum. *Platinum-iridium alloys.*—Pure iridium is very hard and brittle, and the limit of hardness is reached with alloys containing 40 at. per cent. iridium; over this it is not possible to work. With less iridium the alloys have excellent mechanical properties and are practically valuable. The series was studied up to 35 at. per cent. iridium and the curves for electrical and mechanical properties indicate a continuous series of mixed crystals. The effect of annealing below 750° C. is to increase the hardness when more than 10 at. per cent. of iridium is present, but if the temperature of annealing is raised above 750° C., there is a marked decrease of tensile strength. The ductility of the wires is increased by annealing, especially when the iridium content is low. *Platinum-gold alloys.*—This series could not be completely studied, as it is difficult to draw wires with more than 20 at. per cent. platinum.

Refractometer for Determining the Salinity of Sea Water. A. BERGET. (*Comptes Rendus*, clii, 984.)—As it is hardly possible on board ship to determine the salinity by the density measurement by areometers, the total reflection refractometers of Pulfrich and of Abbe were tried. A simplified Féry refractometer was found more convenient. The determination is rapid and only a few cubic centimetres of water are required. Experimenting with known solutions of sodium chloride, the salinity increasing by 0.005 from 0.005 to 0.045, the refractive index rose from 1.333804 to 1.34050 at 16° C., according to a law following a straight line; experiments with diluted sea-water were found satisfactory.

COMPOSITION OF AMERICAN COMMERCIAL GLUCOSE AND STARCH SUGARS.*

BY

A. HUGH BRYAN,

Chief, Sugar Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.

The complete hydrolysis of starch yields the sugar d-glucose, or, as it is commonly known, dextrose. The hydrolysis is supposed to proceed by steps, various intermediate products being formed. These have often been enumerated as soluble starch, maltose and various dextrins. The more complete the conversion of starch, the more d-glucose is formed; the less complete, the more of the intermediate products, which we usually call dextrin. In the United States the starch almost wholly used is from the Indian corn or maize. Some potato starch is used, but only on a very small scale; while in other countries the potato furnishes almost all the starch for these products.

On a commercial scale this conversion is carried on in large copper boilers, or kettles, the starch being mixed with water and acid in weighed proportions and heated under pressure for varying lengths of time. The usual acid in this country was formerly sulphuric, but now hydrochloric acid is the one almost wholly employed. By varying the quantity of acid, the pressure (and thereby the temperature of boiling) and also the length of time of heating, almost any stage in conversion of the starch can be reached. By suddenly reducing the pressure and quickly cooling at any desired stage, the conversion can be stopped. Thus products of varying composition can be made, and in commerce we find these varying products. They are known as commercial glucose, 70 sugar, 80 sugar, and commercial dextrose.

COMMERCIAL GLUCOSE.

This is a thick, viscous liquid never showing crystallization. In its production the time of conversion is short, so as to yield more of the intermediate products than of d-glucose. After conversion the thin liquor is neutralized with soda, filtered, and concentrated by evaporation under low pressure to a thin syrup of about 30 Baumé.[1] Then it is run through bone char and finally evaporated to the desired consistency in vacuum pans. This consistency is expressed in degrees Baumé—so we have from 42° glucose up to 45° glucose, the varying densities being adopted for different uses to which it is put. The color of the commercial glucose varies from water white to brown, although the white products predominate.

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* Read at 2d International Congress of Alimentary Hygiene and Rational Feeding of Man, Brussels, Oct., 1910, and published by permission of the Secretary of Agriculture.

Of the 28 samples given below, 26 are made from corn and 2 from potato starch. The methods of analysis used are as follows:

Moisture: Refractometer and Geerlig's table.[1]

Reducing Sugar: The Munsen and Walker method and tables[2] were used for this determination. An aliquot portion of the solution used for polarization was employed.

Ash: Five grams of the material were ashed at low heat in a platinum dish in a muffle. The ash after weighing was dissolved in water and the per cent. insoluble determined.

Polarizations: Thirteen grams of the glucose were weighed out, dissolved in water, and made up to 100 c.c. Powdered dry kaolin was added and shaken, then the whole filtered. A polarization was made immediately and again after standing 24 hours. The temperature of polarization was 20° C. Fifty c.c. of the solution was transferred to a 100 c.c. flask, 5 c.c. of hydrochloric acid added, and the whole allowed to stand at room temperature 24 hours for inversion. Polarizations on the invert solution were made at 20° C. and at 87° C. A polarization of the direct solution was also made at 87° C.

The results are given in the following table. Averages have been made for each determination and also the maximum and minimum figures. For comparison the averages and means of 10 samples of German glucose and 6 of American glucose, made by Herzfeld,[3] have been added.

Moisture: The average moisture content is 16.47 per cent., with extremes of 20.00 and 11.95 per cent., the variation being due to the concentration of the syrup, some of these samples having a density of 43° B. and others 42° B. The German glucose average is 19.7 per cent.

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[1] *Intern. Sugar J.*, 10, 69–70.

[2] *J. Amer. Chem. Soc.*, 1906, 28. 663.

[3] *Zeit. des Vereins Deut. Zuckerind.*, 1907, 44. p. 614.

Reducing Sugars: The average figure for this determination is 35 per cent., with extremes of 39.56 per cent. to 30.21 per cent. With a content of much above 40 per cent., it is claimed that crystallization is liable to occur. The German glucoses show a much higher reducing sugar content, viz., average 40.7 per cent. and extremes of 47.4 and 36.5 per cent., and were these figures calculated to moisture-free basis, there would be a much wider variation.

TABLE I.

	Ser. No.	Water	Dextrose	Ash	Undetermined	Total	Polarization					
							Direct			Invert		
							20°	87°	87° 1.0315	20°	87°	87° 1.0315
		%	%	%	%	%						
	7420	13.20	37.36	.57	48.87	100.00	181.1	173.5	179.0	180.0	171.4	167.8
	7075	11.95	35.05	.51	52.49	100.00	184.3	176.6	182.2	183.2	174.0	179.5
	7069	13.95	37.27	.56	48.22	100.00	180.0	171.8	177.2	179.6	169.8	175.2
	7421	16.85	35.43	.57	47.15	100.00	173.5	165.2	170.4	172.8	163.0	168.1
	7378	16.75	33.49	.91	48.85	100.00	175.5	168.9	174.2	174.8	166.2	171.4
	7376	16.60	38.49	.30	44.61	100.00	165.8	158.7	163.7	165.0	156.0	160.9
	7086	15.80	38.03	.45	45.72	100.00	169.0	161.0	166.1	168.4	159.2	164.2
	7085	15.35	38.25	.47	45.93	100.00	173.0	162.6	167.7	172.0	161.8	166.9
	7082	16.55	32.05	.60	50.80	100.00	181.8	172.5	177.9	181.2	169.2	174.5
	7081	17.85	33.20	.70	48.25	100.00	175.5	166.9	172.4	174.8	166.8	172.1
	7076	16.30	32.38	.51	50.81	100.00	179.0	170.4	175.8	178.4	167.6	172.9
	7068	16.20	35.56	.43	47.81	100.00	173.4	167.4	172.7	172.8	162.4	167.5
	7067	16.20	37.16	.63	46.01	100.00	175.0	167.8	173.1	174.8	163.4	168.6
	7065	15.85	37.10	.67	46.38	100.00	175.3	167.3	172.6	173.8	164.8	170.0
	7048	16.40	35.15	.59	47.86	100.00	175.4	166.6	171.9	174.6	164.6	169.8
	7047	15.95	34.77	.60	48.68	100.00	175.6	167.9	173.2	174.8	164.8	170.0
	7422	18.60	36.18	.44	44.78	100.00	169.5	161.3	166.4	167.8	158.6	163.6
	7087	16.35	33.05	.50	50.10	100.00	178.4	170.2	175.6	177.4	168.4	173.7
	7379	19.90	33.95	.79	45.36	100.00	166.0	159.1	164.1	166.0	158.0	163.0
	7084	20.00	39.12	.42	40.46	100.00	155.8	150.0	154.7	155.6	146.4	151.0
	7083	15.95	38.95	.39	44.71	100.00	169.1	162.7	167.8	168.6	159.8	164.8
	7077	18.95	30.21	.58	50.26	100.00	174.8	167.1	172.4	174.0	160.2	165.3
	7070	16.95	34.03	.59	48.43	100.00	173.2	165.3	170.5	172.0	165.0	170.2
	7066	18.50	37.43	.40	43.67	100.00	167.9	160.9	167.0	166.0	158.0	163.0
	7045	16.45	31.46	.46	41.63	100.00	181.6	171.0	176.4	180.4	171.6	167.0
	7046	16.95	31.69	.50	50.86	100.00	179.6	169.9	175.2	178.8	167.6	172.9
	5348	15.60	38.00	.24	46.16	100.00	170.0	162.2	167.3	169.0	160.0	165.0
	7377	15.10	39.56	.29	45.05	100.00	171.0	164.3	169.5	170.8	162.8	167.9
Average (28).....	....	16.47	35.51	.52	47.14	100.00	173.9	166.0	171.34	173.1	163.6	168.7
Maximum........	....	20.00	39.56	.91	52.49	100.00	184.3	176.6	182.16	183.2	174.0	179.5
Minimum........	....	11.95	30.21	.24	40.46	100.00	155.8	150.0	154.72	155.6	146.4	151.0
Herzfeld-German, glucose—												
Average.........	....	19.7	40.7	.267	.....	100.00	161.6	.....	......	154 7	.....	.....
Maximum........	....	20.4	47.4	.404	.....	100.00	181.2	.....	......	161.2	.....	.....
Minimum........	....	18.0	36.5	.179	.....	100.00	149.6	.....	......	138.4	.....	.....
Herzfeld-American, glucose—												
Average.........	..	18.7	35.8	.419	.....	100.00	170.6	.....	......	168.8	.....	.....
Maximum........	...	20.1	38.8	.675	.....	100.00	177.0	.....	......	174.0	.....	.....
Minimum..... ..		17.4	33.3	.249	.....	100.00	160.6	.....	......	159.2	.....	.....

Ash: The average figure for this determination is 0.52 per cent., with extremes of 0.91 and 0.24 per cent., by far the larger number, however, ranging around the average figure. The German glucoses show a much lower figure, viz., 0.26 per cent.

average and 0.404 to 0.179 per cent. extremes. This would indicate one of two things: either a larger per cent. of acid is used in the United States or more ash is present in the starch from corn than from potatoes.

Undetermined: No attempt has been made to precipitate the dextrins by alcohol and weigh them, although a study will be made of this later.

Polarizations: Comparison of direct polarization made immediately and on standing 24 hours showed no muta-rotation. The d-glucose evidently is not present in percentages large enough to give this. The results of the immediate polarization are not given in table.

DIRECT AT 20° AND 87°.

The polarizations at 20° average +173.9° V, with extremes of +184.3° V and +155.8° V. For the German glucose the average is +161.6° V, with extremes of +182.2° V and +149.6° V, lower figures than for the American glucoses. When polarizing these solutions in a jacketed tube at a temperature of 87° C. and calculating the reading obtained by the factor 1.0315[4] (100 c.c. of solution at 20° =103.15 c.c. at 87°), there is noted a decrease in the direct polarization, viz., an average of +171.34° V and means of +182.16° V and +154.72° V. In this reading the temperature of the wedges was still 20° and the only change was the temperature of the solution.

INVERT AT 20° AND 87°.

The invert polarization at 20° averaged +173.12° V, with extremes of +183.20° V and +155.60° V. The differences between these figures and those at 20° on direct readings are very small, showing little decomposition of the commercial glucose by the cold inversion method used. The readings made at 87° on the invert solution after correcting for change in volume show a greater decrease from the reading at 20° than was noted in the direct readings at the same temperature, viz., +168.7° V average and extremes of +179.5° V and +151.0° V. This is no doubt due to some decomposition taking place when heating to 87° in the acid solution. With the German glucose, the invert readings average +154.7° V, wth extremes of +161.2° V and

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[4] Bur. of Chem., U. S. Dept. of Agr., Bull. No. 110, p. 17.

+138.4° V. The method of inversion for these figures is not given in the article referred to, but on account of the great differences between the direct reading at 20° and the invert at 20°, viz., average +6.9° V, there must have been some decomposition. However, in Herzfeld's figures for American glucoses, this difference is not so great, averaging +1.8° V; possibly there are present in German glucose substances that are more easily broken down by the acid than those in American glucoses.

STARCH SUGARS.

Three distinct grades of sugars are produced. Wagner[5] gives the following average composition of these:

Determinations	70 Sugar	80 Sugar	Anhydrous * sugar
Water	19.7%	11.2%	4.0%
D-glucose	70.2	79.9	94.6
Dextrin	9.3	8.0	0.7
Ash	0.8	0.9	0.7
Total	100.00	100.00	100.00

* In the opinion of the writer this should be commercial dextrose.

It seems evident, then, that the 70 and 80 refer to the percentage of d-glucose present. By some "70 sugar" is known as "Brewer's sugar" or "Nabob," while "80 sugar" is known as "Climax" or "Acme." These two sugars, while microscopically crystalline in structure, are placed on the market in an amorphous mass somewhat similar in appearance to soap, the former being much lighter in color than the latter. The dextrose is generally in a fine powder, rarely in large crystals.

The sugars result from a more complete conversion of the starch, either from longer and higher treatment or from the use of more acid. After conversion the liquid is neutralized, boiled in evaporators to a desired density and then passed over bone black. The next treatment is concentration in a vacuum pan to the point of crystallization. The product is then allowed to cool for this to take place. In case of dextrose, this cooled product is subjected to further treatment for purification. Some 18 samples of these sugars were examined and may roughly be divided into two classes—crystalline sugar in small granules or balls, such as dextrose, and cake sugars. The latter is again divided into 70 and 80 sugars. The methods of analysis were as follows:

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[5] *J. Soc. Chem. Ind.*, 1909, 28, 347.

Moisture: By drying to constant weight at 70° C. in vacuum on sand.

Dextrose: Same procedure as in commercial glucose analysis.

Dextrin: About 2 grams of the material were dissolved in 10 c.c. of water in a 200 c.c. flask by heating. After complete solution, the flask was cooled and absolute alcohol added to the 200 c.c. mark with shaking. The mixture was corked and allowed to stand for settling of the precipitate. After this had occurred, the clear liquid was poured off, the precipitated dextrins were washed with 95 per cent. alcohol, water was added and the precipitate dissolved and washed into an ordinary tared moisture dish. The water was evaporated off over steam bath and the dish and contents heated to constant weight in a vacuum oven at 70° C. The weight of the precipitate was thereby determined. The dried precipitate was again dissolved and its reducing sugar content determined in the usual way. The above weight was then corrected for the weight of the d-glucose found and the percentage of dextrin thereby calculated.

Ash: In same manner as for commercial glucose.

Polarization: Ten grams of the material were dissolved and made up to 100 c.c. Dry powdered kaolin was added and shaken, then filtered. The solutions so prepared were allowed to stand for 24 hours to come to constant polarization. The reading so obtained was multiplied by 3.284 (the factor for normal weight of dextrose when polarizing a 10 per cent. solution).

The first three sugars show little variation in composition, but the ash of two is higher than that of the other one. The d-glucose by polarization is higher than by reduction, but in two cases the results agree fairly well. The next three sugars show a rather even composition. Their appearance was the same, but obtained from different makers and in different sections of the United States. The water content of these was about double that of the first three and the d-glucose content about 9 per cent. lower. The per cent. of undetermined matter is much larger than in the former class.

The two samples of 80 sugars show a rather even composition. The percentage of d-glucose varies only about 0.6 per cent. and the moisture content only 1.5 per cent. The ash is much higher than that of the samples just discussed, and the per cent. of undetermined also has increased.

The 70 sugars do not show a very even composition. The d-glucose varies from 66.6 per cent. to 73.16 per cent. The percentage of dextrin in two samples is much higher than in the other cases, being over 2 per cent. Dextrose by polarization in three cases gives over 100 per cent. This comes about from the presence of a large quantity of the intermediate products of starch conversion having high specific rotatory power. The undetermined matter has increased a little over that present in the 80 sugars. This, of course, is to be expected, as in the 70 sugars conversion has not been carried as far as in 80 sugars and there exists a larger percentage of these intermediate products.

TABLE II.

Ser. No.	Appearance	Water	Dextrose	Dextrin	Ash	Undetermined	Total	Polarization	
								10g to 100cc	Dextrose 32.84*
				CRYSTALLINE SUGARS.					
		%	%	%	%	%	%	°V.	
6998	Cream granulate	5.04	90.70	.52	.97	2.77	100.00	28.65	94.08
7026	Cream granulate	5.10	89.96	.16	1.06	3.72	100.00	27.70	90.96
7019	Cream granulate	5.67	89.36	.54	.48	3.95	100.00	28.00	91.95
7012	Balls small......	9.57	82.68	.31	.62	6.82	100.00	27.50	90.31
7009	Balls small......	9.94	81.52	.37	.64	7.53	100.00	27.70	90.96
7000	Balls small......	9.21	83.76	.44	.64	5.95	100.00	27.80	91.30
				CLIMAX OR 80					
7007	D'k yellow cake.	10.61	77.24	1.15	1.17	9.83	100.00	28.40	93.20
7029	D'k yellow cake.	9.06	77.84	.96	1.18	10.96	100.00	26.50	87.03
				NABOB OR 70					
6999	L't yellow cake.	13.77	72.32	.57	1.08	12.26	100.00	26.15	85.88
7006	L't yellow cake.	16.55	67.46	1.45	.95	13.59	100.30	30.30	99.50
7011	L't yellow cake.	15.66	70.64	.60	.94	12.16	100.00	26.30	86.37
7024	L't yellow cake.	16.65	70.12	1.24	.47	11.52	100.00	30.30	99.50
7025	D'k yellow cake.	15.76	73.16	.81	.97	9.30	100.00	25.10	82.43
7027	L't yellow cake.	17.33	66.72	2.42	.45	13.08	100.00	33.45	109.85
7001	L't yellow cake.	18.03	69.70	.65	1.00	10.60	100.00	24.90	81.77
7005	L't yellow cake.	17.74	70.12	.67	1.12	10.35	100.00	28.45	93.42
7028	L't yellow cake.	17.63	66.60	.94	.48	14.35	100.00	32.50	106.73
7023	L't yellow cake.	15.20	71.28	2.32	.52	10.68	100.00	32.00	105.09

* The normal weight of dextrose polarizing 10 grams to 100 c.c. is 32.84 grs.

Treatment of Sulphated Storage Cells. G. A. PERLEY. (*J. of Phys. Chem.*, xv, 489.)—When a lead accumulator is neglected lead sulphate forms over the surface of the plates, while the capacity of the cell drops towards, or even as low as, zero. Various methods of renovation have been proposed, and the conclusions as to their merits are: (1) A badly sulphated cell can be restored by charging at the normal rate in a sodium sulphate solution. (2) It is desirable, but not necessary, to use lead "dummies" outside the end plates. (3) The concentration of sodium sulphate may be varied within wide limits, but 200 grams of the crystallized salt per litre are recommended. (4) The sodium sulphate must meet the requirements as to purity which are prescribed for battery acid. (5) The cost of electrical energy to restore a 40 ampère hour cell should not exceed 10c. (6) Since sodium sulphate is not deleterious to the cell, it is not necessary to wash the solution completely out of the pores of the plates. (7) It has been stated that a cell can be restored by charging at half the normal rate for a long time in the regular battery acid; but it is probable that the time and electrical energy required would be excessive in the case of very badly sulphated cells.

Magnesium. ANON. (*Eng. Min. J.*, xcii, 12.)—The consumption of magnesium in the United States in 1910 was no greater than in 1909, the total value being about $12,000. This metal seems destined to have a much wider use in the future, as magnesium is of greater value than aluminum for refining steel; and also because great interest is now being aroused in the remarkably light and strong alloys produced by the proper admixture of small amounts of zinc with magnesium. These alloys are stronger than aluminum alloys and have a specific gravity of about 1.8 as against 3.0 for the lightest commercial alloys of aluminum. It is reported they are extensively used in aeroplane manufacture. Alloys of magnesium with 2 to 4 per cent. of zinc can be wrought and rolled, and have a fracture like fine steel. They can be readily cast and turned, like brass or copper, without the use of soap or petroleum and they resist the action of air and water. Considering that bulk for bulk magnesium can be manufactured at less cost than aluminum, it will necessarily become a strong competitor of the latter metal wherever great lightness is desirable. The price now is $1.25 per 1 lb., but it is expected to come down to 50c. in the near future.

Manganese Bronze. ANON. (*Iron Age*, lxxxviii, 2, 93.)—The Committee of the American Society for Testing Materials is of opinion that the term "manganese bronze" should be applied to metal conforming to the following limiting analysis: Copper 55 to 60 per cent., zinc 39 to 45 per cent., iron not over 2 per cent., tin not over 2 per cent., aluminum 0.5 per cent., manganese 0.5 per cent. This is a proposed standard definition on which the Society has not yet voted.

AN EXPERIMENTAL STUDY OF VORTEX MOTIONS IN LIQUIDS.

BY

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(*Concluded.*)

PHOTOGRAPHY OF VORTEX RINGS.

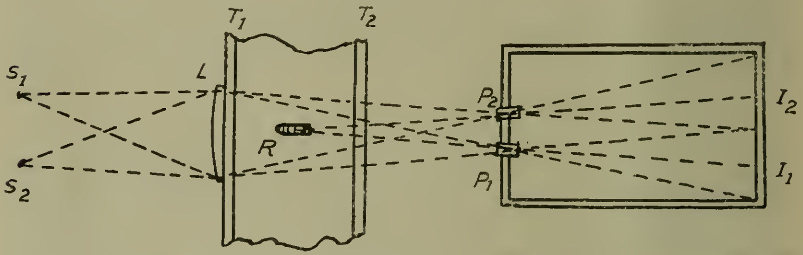
THE problem which was presented of photographing fluid vortices proved to be one of very great difficulty. It was, indeed, over a year after the first attempt at solution before a satisfactory one was found. In the beginning the facilities available were inadequate and interruptions were frequent during the course of the experiments.

At the outset it was decided to take stereoscopic views, practically full size, and, if possible, so nearly instantaneous that, with the swiftest motions, there would be no lack of sharpness in the photographs. A little calculation will show the briefness of the interval required for a successful exposure. Some of the negatives were made from rings moving at the rate of 20 mm. in 1/80 of a second. If the photograph is to show clear and sharp under a lens no part of the ring should move over 1/20, or certainly not over 1/10 mm., during the time of an exposure. Hence the exposure should not last longer than from 1/16,000 to 1/32,000 of a second.

No mechanical shutter could be constructed to give so short an exposure. At first this fact was not fully appreciated, and a few preliminary trials were made in which a steel shutter moved by a powerful spring was used. Views were obtained, but the delicate details were all absent. It was then rightfully concluded that the photographs must be made with an electric spark, which preferably should not last over 1/50,000 of a second. As the intensity of the light must be great in proportion as the time of exposure is reduced, and as the light must pass through 12 cm. of water besides two plates of glass and at least two lenses, it was necessary to devise means of obtaining a light of very great intensity and quantity.

In photographing falling drops of a liquid, as was done so beautifully by Worthington, the time of fall through a given height in air could be depended upon as fairly constant. The reproducibility of the speed of the vortex rings could not, however, be so depended upon. Experiments showed that it was impossible to so exactly regulate the force of the blow on the diaphragm of the gun and other necessary conditions that the velocity of the rings could be relied upon to be twice quite alike. All difficulties, except the last, were overcome, and this proved not to be serious in the end. The optical method employed giving complete success, and which I think could not be improved upon, was as follows:

FIG. 7.



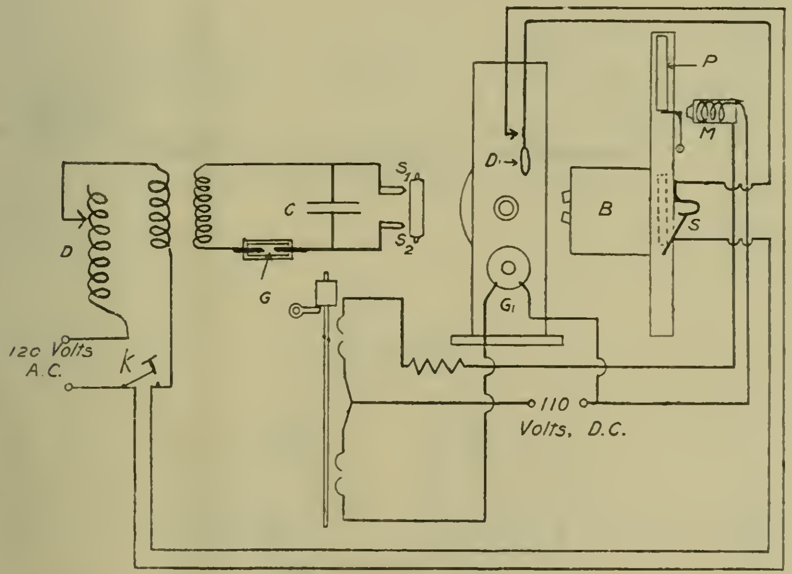
A plano-convex lens, L, (Fig. 7) 12.5 cm. in diameter, was held in a frame against one of the glass sides of the tank. The lenses, p_1 and p_2, of the stereoscopic camera were placed as shown in the diagram, 25 cm. from a plane midway between and parallel to the sides of the tank. The camera was adjusted to give a focus at 25 cm. The two stereoscopic images of the ring R would thus appear full size upon the photographic plates. Two sources of light, s_1 and s_2, were located back of the lens in such positions that the image of s_1 was focussed on the lens p_1 and the image of s_2 on the lens p_2. This arrangement projected upon the camera plates I_1 and I_2, two brilliant circular disks of light of uniform brightness. The ring thus appeared in the camera as a dark object against a brilliantly lighted background.

If a suitably moving photographic plate and the vortex ring R are as indicated, when instantaneous flashes simultaneously occur at s_1 and s_2 stereoscopic negatives are secured. A variety of makes of photographic plates 3½ by 6½ inches were tried. The most rapid plate tried was the Lumiere-Sigma, but Seed plates and Eastman plates also gave satisfactory results.

Methods of producing strong flashes of light at s_1 and s_2 received considerable study and experimentation before a satisfactory one was hit upon. The arrangement finally employed is shown in Fig. 8.

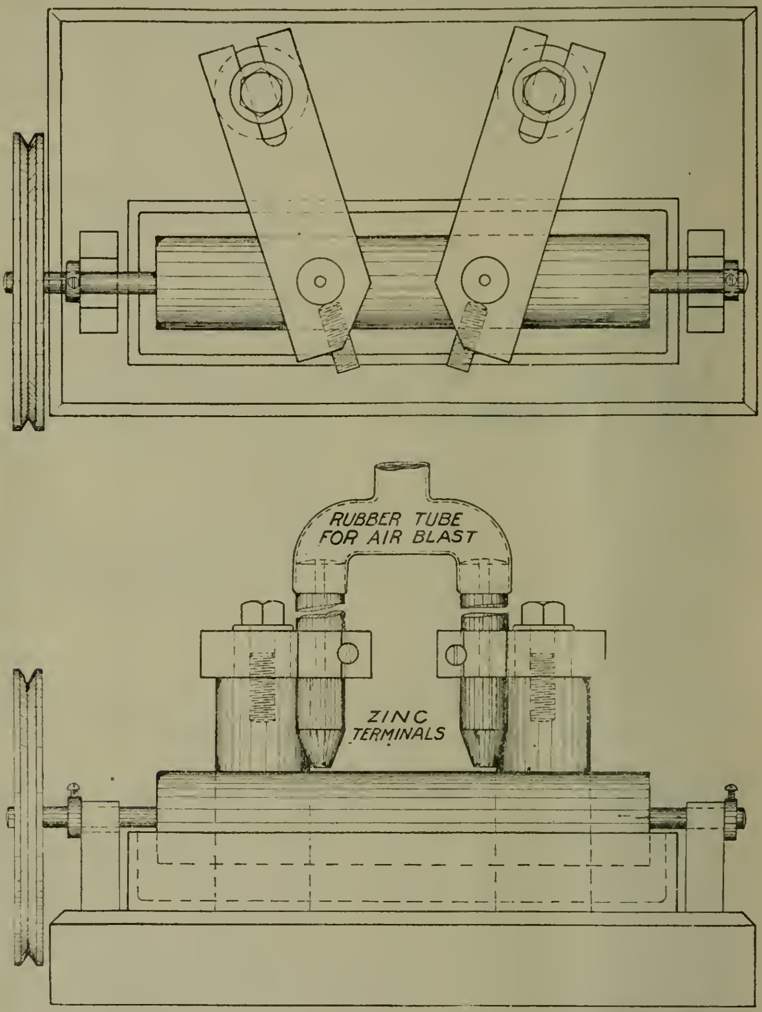
A generator of several kilowatts capacity supplied alternating current of forty cycles at 120 volts to the primary of a transformer having a transformation ratio of 1/100. In the circuit with the primary of the transformer there was a variable inductance D of low ohmic resistance. In circuit with the secondary of the transformer were the two spark gaps s_1 and s_2, in series, and together in shunt with a high tension condenser C. The capacity of this condenser was .013 M.F. It was also found necessary in regulating the discharges at s_1 and s_2 to introduce an adjustable air gap at G. This air gap consisted of two steel rods 7 mm. in diameter inserted into the opposite ends of a porcelain tube and separated from each other, near the centre of the tube, by about 1 cm.

FIG. 8.



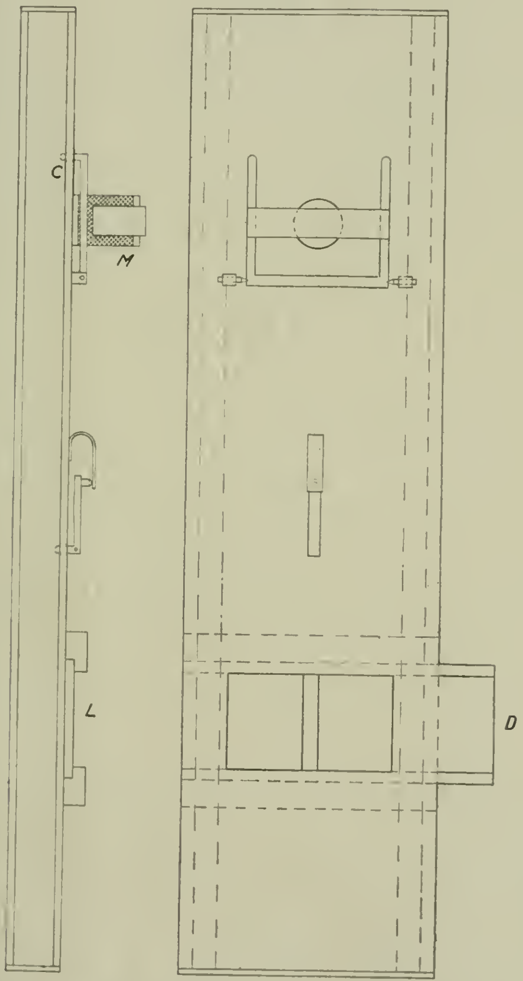
The problem was to make such adjustments that only one discharge would occur at the air gaps s_1 and s_2 during the time of each alternation of the generator current, or 80 discharges per second. It was arranged to have the dropping photographic plate P fall in 1/80 of a second through a distance equal

FIG. 9.



to the diameter of one of the illuminated areas on the plate. Thus two successive illuminated areas on the plate would touch, tangent to each other, and not overlap. If the plate were a long one, three or four round disks of deep black (in the negative) would be photographed upon it during its passage past the back of the camera box B. If the ring happened to be in

FIG. 10.



the field of view while the plate was passing the camera box, two, three, or even four views, 1/80 of a second apart, might be secured.

The design of the spark gaps s_1 and s_2 was carefully worked out to give necessary uniformity in the discharges, as well as the greatest possible brilliancy and actinic power to the light.

The construction of this double discharge gap is shown in Fig. 9. It consists of three essential parts, a trough of mercury, a rotating cylinder of brass dipping into the mercury, and two upright rods of zinc to which the high-tension terminals of the transformer are joined. The discharge takes place between the amalgamated ends of the zinc rod and the amalgamated mirror-like surface of the rotating brass cylinder. The parts were made sufficiently large to run quite cool. A small motor maintained the brass cylinder in rotation at a moderate speed. It is thought an air-blast as shown in the figure would have been an improvement as tending to steady the discharge and keep it more regular. It too frequently happened that, due to inability to hold conditions constant, two or more discharges occurred during a half cycle and negatives were spoiled.

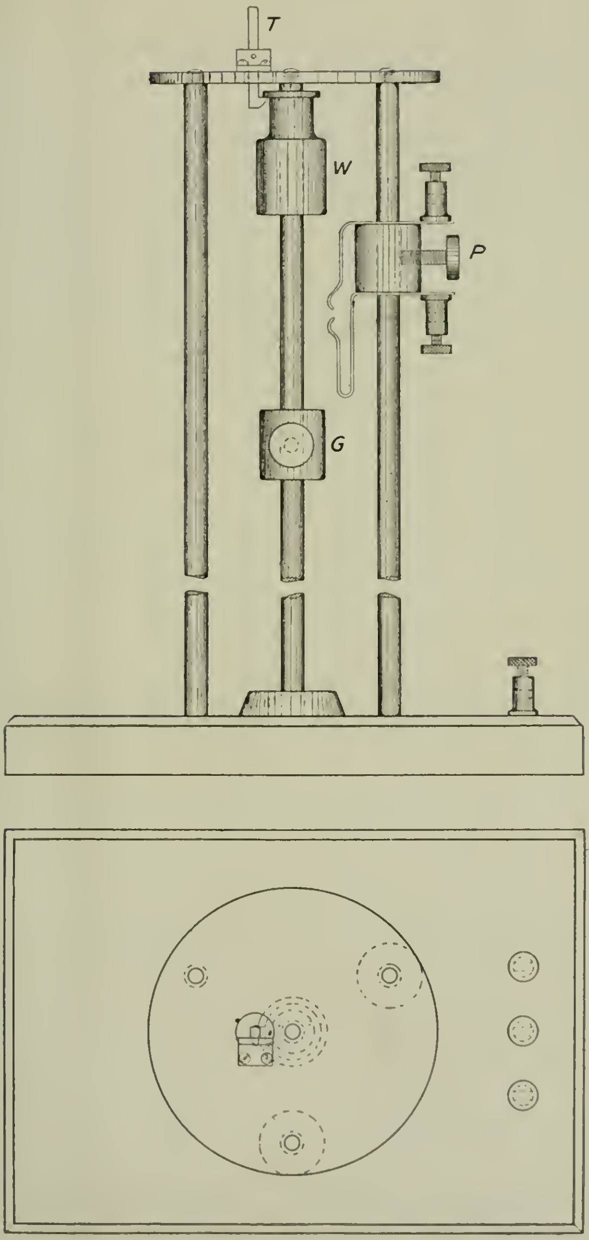
The plate slide is plainly shown in the general view, Fig. 3, and in more detail in Fig. 10.

As two plates had to be dropped at exactly the same time, a brass frame was constructed which held the two plates in rigid relation to each other. The plates were put in this frame, and when it was released by the magnet M and the catch C, Fig. 10, fell between two steel guides, shown in dotted lines. It was caught in a light-tight bag held below the slide. The guides for the plate frame were covered and made light-tight. A sliding door D, opposite the back of the camera, could be opened and ground glass inserted in place of the plate and in this manner the camera focussed.

The timing of the fall of the plates and the arrival of the ring in the field of view, so that it would be properly caught upon the plates, was accomplished in the following manner: A metal weight was so arranged that, upon releasing a catch, it would fall and make electric contact between two spring terminals in the circuit of an electric magnet, thereby releasing the plate frame; then, after a short definite time, the falling weight made contact between two other spring terminals, closing the circuit through the electromagnet gun. This timing device is shown in Fig. 11.

The relative positions of the first and second pair of contact springs could be adjusted to regulate, to a nicety, the interval

FIG. 11.



between the release of a plate and the energizing of the gun magnet. To determine the proper positions at which to set the above two contacts the following procedure was adopted: There was first suspended in the tank of water a small disk (D_1, Fig. 8) at the exact position where it was desired that the ring should be at the moment of the exposure. When a ring was projected so as to strike this disk, it would close by its impact upon the disk an electric circuit. The contact was in circuit with the primary of the transformer and also in circuit with another contact (S, Fig. 8), which normally remained closed, but which the falling of the plate frame would open at a moment when the plates were in a position to receive the image of the ring. When the trigger released the contact weight, magnet M, Figs. 8 and 10, first released the plate frame, then after an interval the gun magnet G_1 was energized, and if the ring reached the disk before the plate frame reached its exposure position, the circuit through the transformer was closed and a flash of light at the spark gaps occurred. If, however, the plate frame reached the exposure position before the ring reached the disk, the primary circuit of the transformer was open and there was no flash of light at the spark gaps. An up-and-down adjustment was made of the pair of contact springs in circuit with the gun until a flash of light of the briefest possible duration was seen. This completed the timing, which meant that the ring reached the disk at the same instant that the plate frame and plate reached the exposure position. The disk which the ring was made to strike was then removed from the tank and the circuit short-circuited at K.

By the above procedure and adjustments everything was put in readiness for exposing the plates. To decrease the danger of fogging the plates, the work was usually done at night. When all was in readiness, the main circuit switch was closed to start the spark, and the timing weight was released. This last started the plate frame on its fall and after a short interval fired the gun. The plate frame was caught in a bag and carried to the dark-room for development. There resulted, on the average, about one drop out of five which gave photographs worth preserving. There were so many things to be kept in exact adjustment at the same time that numerous failures were inevitable. The expense for plates was considerable, and the innumerable trifles which persisted in going wrong at a critical moment were often discouraging.

After about thirteen first-class pairs of stereoscopic views had been secured and about twice this number of single views, it seemed that the research was consuming time out of proportion to the value of the results being obtained, and the writer did not feel justified in continuing the investigations further. The negatives secured, however, especially the stereoscopic ones, were sufficient to show, in a very adequate way, the precise character of the phenomena under investigation.

As the light was quite sufficient, a strong developer could be employed, and only about five minutes, as a rule, was consumed in the development of one pair of plates.

The developer employed was usually made up shortly before it was used and according to the following formula:

Water	10.7	ounces
Metol	0.5	gram
Hydroquinon	2.1	grams
Sodium sulphite	7.85	grams
Sodium carbonate	14.3	grams

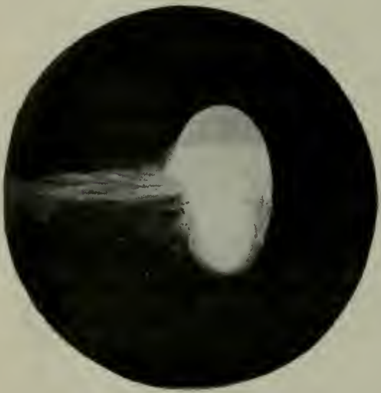
This was put in a bottle with a tight glass stopper, and it was found to keep without deterioration when the bottle was kept filled. Before using it was diluted with an equal quantity of water.

Views of rings at the moment when changing from water into oil, and at the moment of reflecting from an oil or water surface, might have been obtained by a sufficient expenditure of time and care.

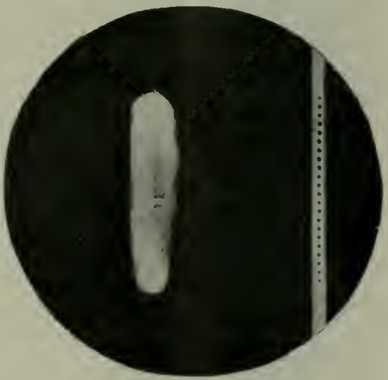
From necessity the photographs were taken of the rings viewed very nearly edgewise; that is, normally to their direction of motion through the tank. It would have been interesting if views could have been secured through the lens in the end of the tank. These would have shown the rings as they appear when approaching the observer. The problem of illumination, however, was difficult, and no serious attempt was made to solve it. It was at first thought that milk-white rings might be sufficiently illuminated to be photographed by reflected light, but when this was tried with white rings of silver chloride they were found to phosphoresce for too long a time to enable instantaneous photographs to be taken, even had the illumination been sufficient, which is doubtful.

View A, reproduced to be viewed in a stereoscope, is of a single ring distant a few centimeters from the gun. It has at this point a characteristic mushroom appearance and is followed by a trail of color. This ring, when photographed, was moving about one and a half meters per second. In View B is shown another ring which has also just left the gun. It probably started with a higher velocity than the ring shown in the previous view, and its mushroom head and trail present a smoother appearance. View C shows a ring which has gone about 30 centimeters from the gun. It started with the same appearance as the ring in View A. The trail has entirely disappeared. It also is moving more than a meter a second and is about to strike a small watch chain suspended vertically in the water. View D is of another ring taken under conditions similar to the conditions under which the ring in View C was taken. View E is of another ring, a greater distance from the gun, in which the coloring matter is less dense. If carefully observed, small dark particles may be seen to be distributed along the filamentary axis of the ring. The position of these particles does not clearly appear in a single view, but when a double view is observed in a stereoscope

VIEW B.



VIEW C.



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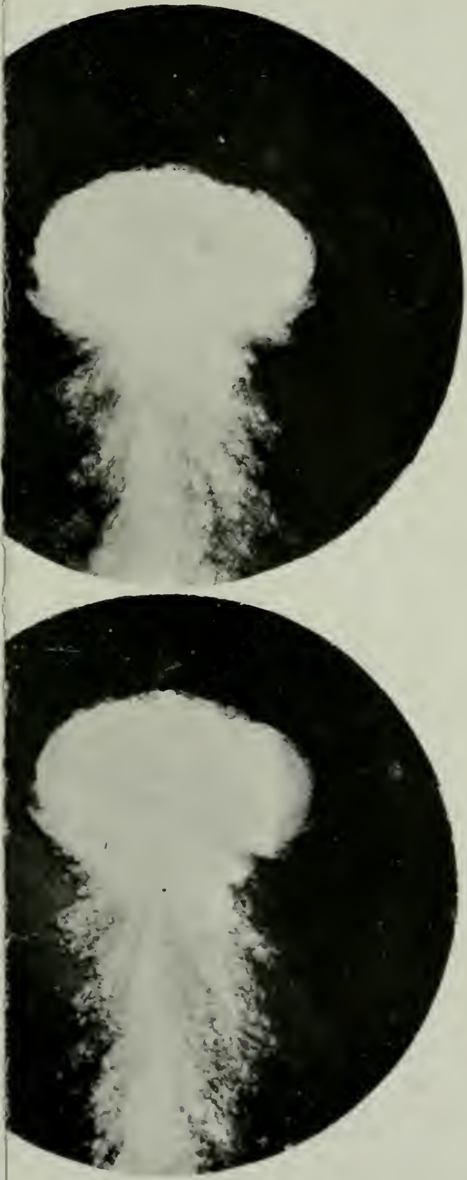

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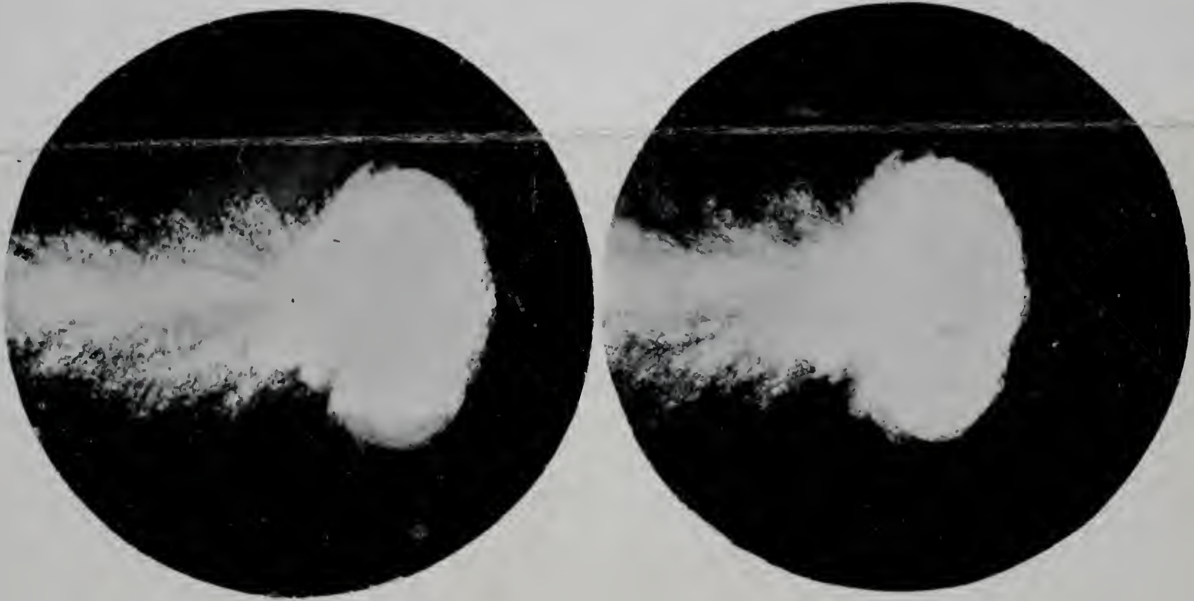
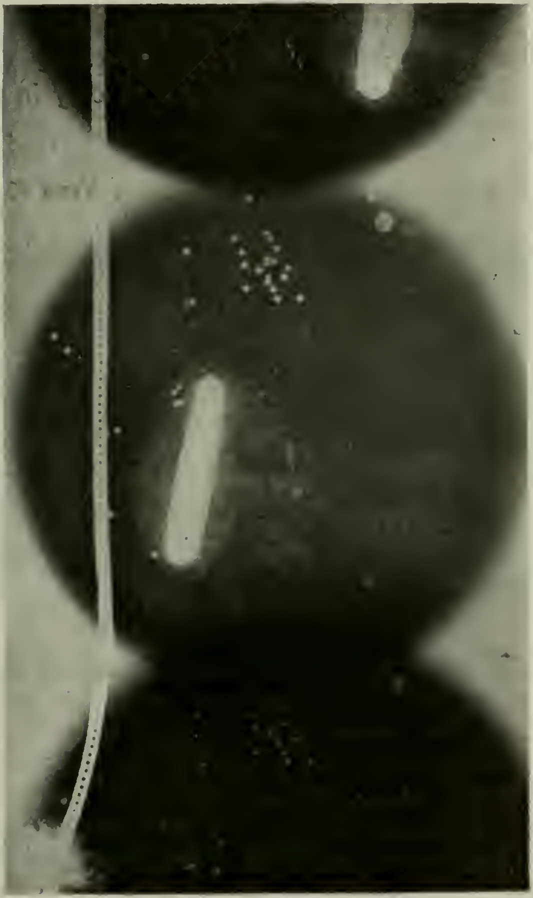
View A.



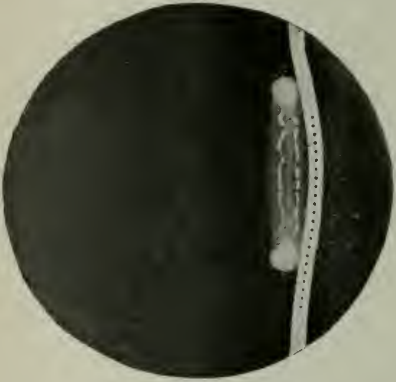
they are plainly seen to lie along the axis of the ring. In many of the views this line of dark particles is shown very clearly. While it was supposed that the coloring matter

VIEW F.

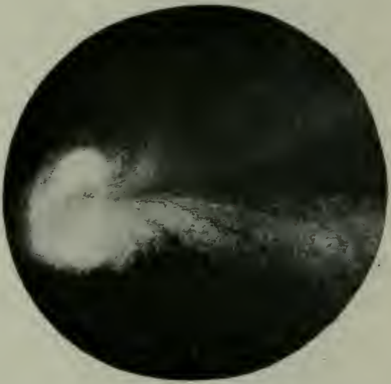


of the ring was free from suspended particles, some must have been present originally in the ring or were gathered up by it in its progress through the water. As a vortex ring throws off particles denser than the material of the ring itself, particles which are retained in a water ring must have a density of less than water. In F we have three views, slightly smaller than the others, of the same ring, taken about 1/50 of a second apart, showing the ring just before and just after it has struck the chain. View G shows remarkably fortunate timing. The ring has moved up to, but has not actually struck, the chain. It will be noted that the chain bulges most on a line from the centre normal to the plane of the ring. The filamentary core of dark particles also shows well in this ring. The core, which seems always to be present, can generally be seen only in rings which are but slightly colored.

VIEW G.



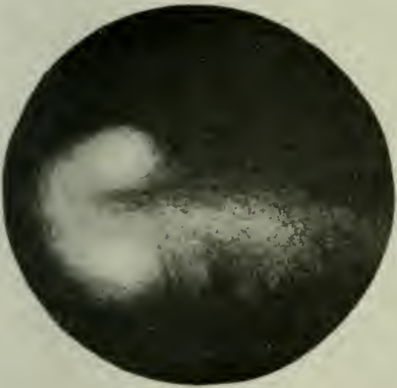
VIEW K.



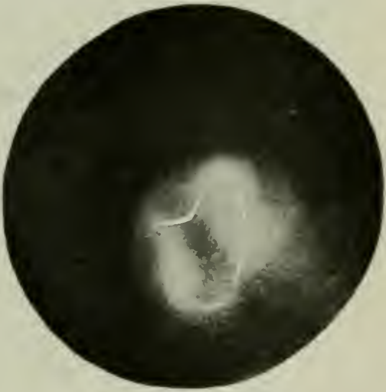
When the diaphragm of the gun is provided with two circular holes, one above the other, two rings are ejected at the same instant. The action upon each other of the two rings ejected is, perhaps, the most interesting property of these vortices. To study this action a large number of exposures of double rings were made and a few very instructive negatives secured. These views were all taken stereoptically, and to learn all they teach should be viewed in a stereoscope. Negatives were obtained of the double rings just as they were leaving the gun and also at different distances up to half a meter. In View H double rings are shown which have issued about 5 cm. from the gun. There is less coloring matter in the upper ring than in the lower, which permits the internal construction of the upper ring to be more clearly seen. Both be noted that the vortex has become cleared of all surrounding

View D.

View L.

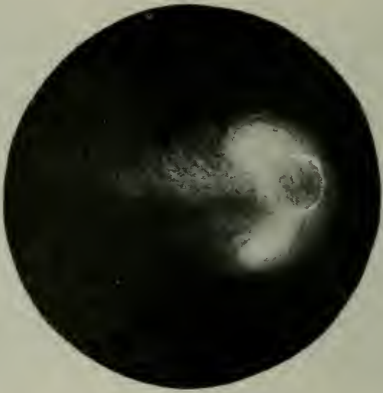


View M.



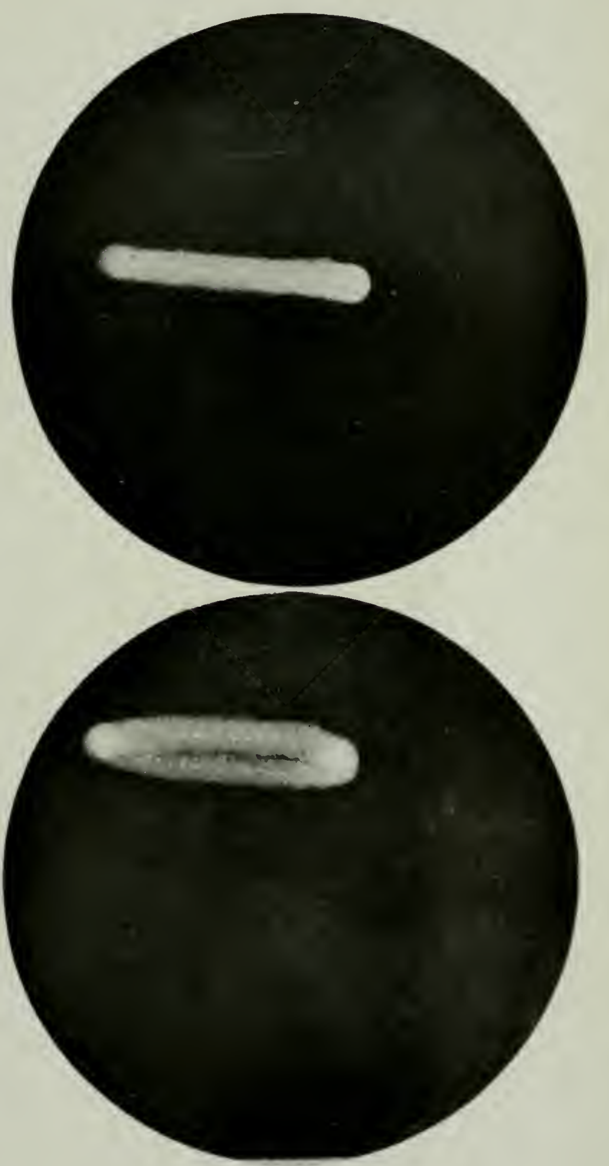
rings have the mushroom appearance characteristic of single rings just issuing from the gun. There is already an indication in this picture that the two rings are being attracted towards each other, and their planes are seen to be slightly tilted in the direction of their forward motion. The next view, I, shows two other rings a few centimeters farther from the end of the gun. The attraction towards each other and the tilting of the planes of the rings are here still more pronounced. In the following view, J, are shown two other rings a centimeter or two farther from the gun than the previous pair. Here the attraction has become so great that the rings have joined. The dimly-seen cores of the separate rings, now become a single ring, show a peculiar outline, somewhat like the letter C, when viewed from a position at right angles to the forward motion of the ring. In View K the two rings have completely joined, but their trails extend back along the separate paths which they had previously followed. View L gives a slightly later stage of a double ring. In View M the vortex has become a distorted ellipse, with major axis normal to the plane of the paper. View N also shows a newly-formed double ring. View O is a ring in which the joining of the two separate rings is completed. Its phase of vibration is such that it is convex upon the side facing its direction of motion. It should be noted that the vortex has become cleared of all surrounding coloring matter. In View P is shown another ring, also made up of two separate rings, as it appears in three successive stages separated by intervals of about 1/50 of a second. Here are plainly seen the four kinds of motion possessed by liquid vortices which have been formed from the union of two single rings. First, there is a rotation about the vortex filament; second, the forward motion of the vortex as a whole; third, a motion of oscillation of the extremities of the vertical diameter of the vortex in a vertical plane lying parallel to the direction of forward motion; and fourth, a motion of oscillation of the extremities of the horizontal diameter of the vortex in a horizontal plane parallel with the line of motion of the vortex. These four motions, except the second, are too rapid to be observed satisfactorily with the eye. But the instantaneous photographs here reproduced fairly demonstrate the nature of these motions, and the stereoscopic views especially enable their character to be accurately observed.

VIEW N.



PHYSICAL EXPLANATIONS OF VORTEX MOTIONS.

Various physical and mathematical treatments of vortex motions that have been given by Helmholtz, Lord Kelvin, Lamb, J. J. Thomson, and others, are based, in the main, upon the assumption that the medium in which the vortices exist is a



View E.

so-called "perfect fluid." In Thompson and Tait's Natural Philosophy, Vol. II, § 742, the definition given for a perfect fluid is as follows: " . . . a body incapable of resisting a change of shape; and, therefore, incapable of experiencing distorting or tangential stress. Hence its pressure on any surface, whether of a solid or of a contiguous portion of the fluid, is at every point perpendicular to the surface." In § 320, Vol. I, the same authors say, " . . . a mass which is absolutely incompressible, and absolutely devoid of resistance to change of shape, is given the simple appellation of a liquid."

VIEW P.

A *liquid* of this character, which is an incompressible fluid, is the ideal or perfect liquid of the mathematician. A *fluid* may be perfect and yet be a compressible fluid in which the density is a constant function of the pressure. Water does not fulfil Kelvin's definition of a perfect liquid, chiefly because of its viscosity. It is, however, nearly incompressible and relatively free from internal friction, and therefore is the most suitable of any known liquid for the experimental study of vortex motions.

Vortex motions may be studied from two diametrically opposite points of view: the mathematical and the experimental.

From the former the mathematician attempts to deduce from a few fundamental assumptions the nature of vortex motions in a so-called perfect fluid and then to predict how the viscosity of actual fluids will modify these motions.

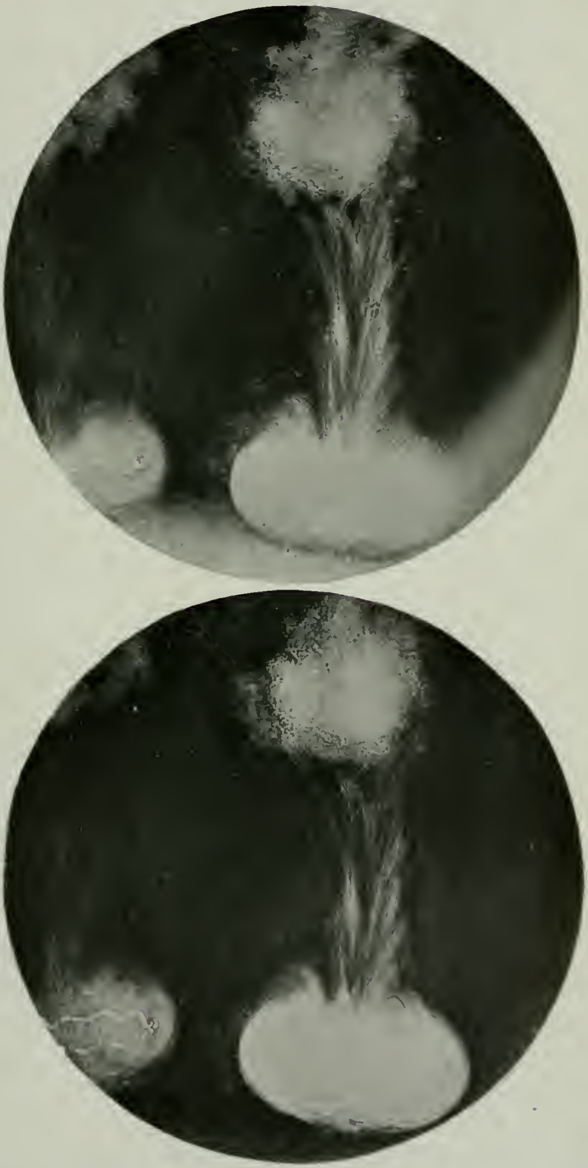
From the latter the experimentalist observes the motions in actual fluids and then reasons how they might become modified if the viscosity were to become indefinitely small. The experimental method was chosen because it is better within our capabilities and because it was believed that all actual physical problems are more likely to find their solutions when actual rather than ideal types of matter are dealt with.

The purely physical explanations, which follow, of the nature of the motions of vortices in actual liquids, may not accord in all cases with the conclusions of mathematical examinations of motions in assumed perfect fluids.

In a perfect fluid, according to the mathematicians, a vortex can never be created, or, if in existence, it cannot be destroyed. In water the vortex is easily formed and easily destroyed, while the manner of its formation is not difficult to understand.

The creation of vortices in actual fluids, their mutual action upon each other, and many peculiarities of their motions are explicable by the application of a theorem announced by Bernoulli in the 18th century. The meaning of this theorem should be clearly understood as a preliminary to any physical explanation of vortex motions.

Let the attention be fastened upon a single cubic centimeter of the liquid in the tank. Let this single cubic centimeter be h centimeters below the surface, and let the density of the liquid in the tank be d, then the mass of the single cubic centimeter will be d grams. If g is the acceleration of gravity, the weight



View H.

of this cubic centimeter will be $g\ d$ dynes. Now if the imaginary cubic centimeter of liquid were lifted from its position h centimeters below the surface to the surface, the quantity of work done would equal $h\ g\ d$ ergs. Or, if we conceive the cubic centimeter of liquid replaced by a massless cube one centimeter along each edge, the work done by the rest of the liquid in raising this cube to the surface would be, as above, $h\ g\ d$ ergs. Hence the potential energy of this cubic centimeter of fluid is,

$$P_p=h\ g\ d.$$

Next conceive this same cubic centimeter of liquid to have a velocity in any direction of v centimeters per second. It would then have a kinetic energy $\frac{1}{2}\ d\ v^2$. The imaginary cubic centimeter of liquid also has additional potential energy, due to the fact that the liquid of the tank is under atmospheric pressure. This potential energy will be readily understood if we conceive a fine tube to have one end in the centre of the imaginary cube of liquid and its other end in a vacuum. The imaginary cube of liquid, if located at the surface of the liquid, would tend to flow into the vacuum with a force depending upon the pressure of the atmosphere. The potential energy due to this cause alone is simply the pressure per square centimeter upon the surface of the liquid. Call this energy p. These last statements become clear by considering that the work required to force a volume V of liquid from the vacuum back into the tank is pV. The area of the piston, multiplied by p, is the force, and the product of the force by the length of the stroke is $p\ V$, and is the work done. Hence if V is made a unit volume the work is p; that is, the potential energy due to the pressure on the liquid, per unit of volume, is simply p.

By the principle of the conservation of energy, the sum of the potential and kinetic energies of any portion of the fluid (friction neglected) must remain constant. Hence we have

$$p+g\ d\ h+\tfrac{1}{2}d\ v^2=H, \text{ a constant.}$$

This important relation, known as Bernoulli's theorem, is to the effect that, if at any point in a fluid the velocity of the fluid increases, the pressure which the fluid will exert normally to its direction of motion will correspondingly decrease. Upon Bernoulli's principle depends the action of the aspirator, the injector, the atomizer, the curving of golf- and base-balls, and many other phenomena familiar in aero- and hydro-dynamics. It is the sufficient principle for explaining most of the phenomena of liquid vortices.

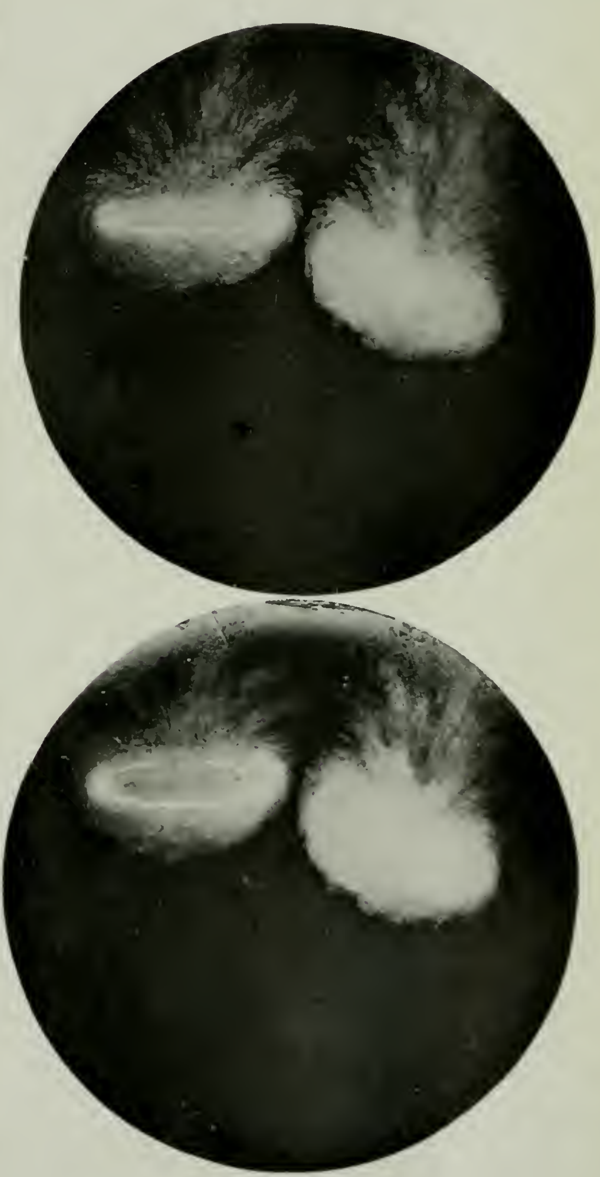
By suitably choosing the origin of axes we may write $h=0$, when the above expression becomes

$$p+\tfrac{1}{2}d\ v^2=C, \text{ a constant.}$$

Let us consider, with this principle in mind, what happens when the diaphragm of the gun is struck a blow (Fig. 12). The diaphragm moves suddenly from p to p_1, and the stream-lines of the liquid, outside the orifice, will be somewhat as indicated in full lines. After the liquid has issued from the orifice it might have been expected to move as indicated in dotted lines. Instead, however, the stream-lines of its flow bend into spirals, as roughly indicated by the heavy lines, every particle moving towards a point where the pressure is diminishing. Now it is evident, from Bernoulli's principle, that at the edge of and just outside of the orifice the velocity of the liquid will be high and the side pressure low; hence any particle which has reached a position as *a* will be urged not from but toward the edge of the orifice, and move in a curved path approximately circular. The ring once formed continues to move forward, and the particles of liquid in it rotate rapidly about a circular centre called the vortex filament. At the beginning of motion, however, an additional body of liquid is carried along with the vortex, which is afterward left behind as a trail. The general contour of this additional body of liquid is shown in Fig. 12 by the broken heavy lines. It is due to this that a vortex possesses the peculiar mushroom appearance shown in Views A and B, taken shortly after it has left the gun.

After the ring is completely formed we have the case of particles of fluid in rapid rotation about an axial line, and the query naturally arises, why the substance of the ring is not thrown off tangentially by the action of centrifugal force.

Such, indeed, would be the case if the vortex filament did not form a closed loop. If the substance of the ring were thrown off by centrifugal force it would of necessity be replaced by other portions of the liquid. Now as the ring is closed upon itself, and as centrifugal force acts equally at every tangent to

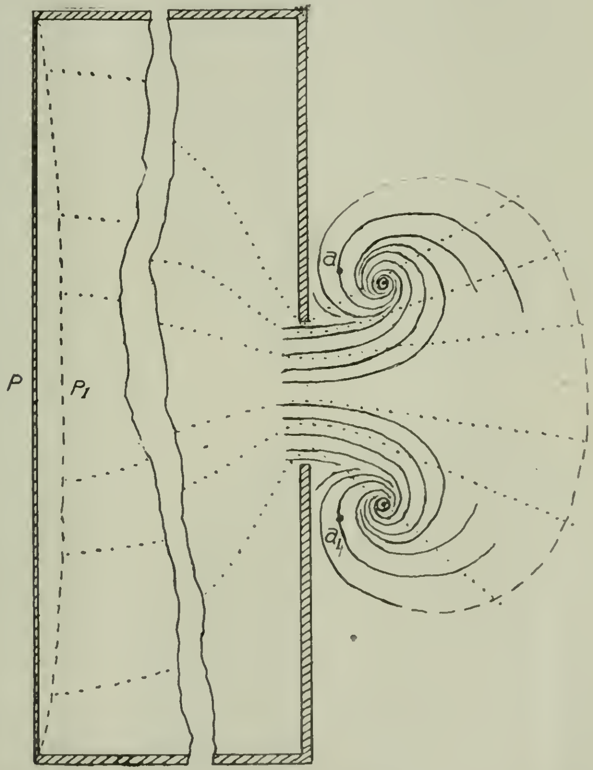


VIEW I.

injector

a cross section, there is as much tendency for the particles of the ring to leave at one point of its surface as at another, and so even should a particle leave at a given point there would be no tendency to its replacement by a particle leaving at another point. Furthermore, as the velocity of the particles at the circumference of the ring is high, there will be, by Bernoulli's principle, a radial pressure acting toward the filament of the vortex.

FIG. 12.

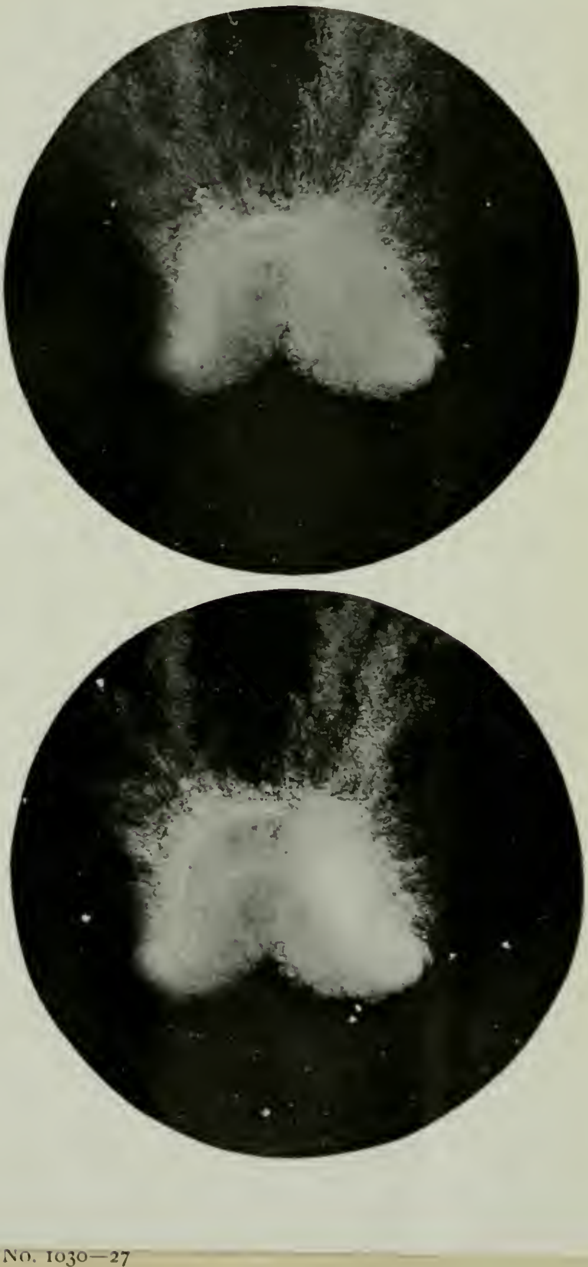


If the attempt be made to form a vortex of a more dense fluid in a less dense one, as a vortex of carbon-tetrachloride in water, a condition of instability exists, and the more dense particles of the vortex actually do fly off, impelled by centrifugal force. If a vortex ring is moving through water, filled with finely-suspended particles, as ground Indian meal, denser than water, it will not pick up the particles. If, however, the suspended particles are less dense than water they will be swept into the vortex and carried along with it.

It is on this principle that oil rings are formed out of water rings. Assume a layer of oil on top of the water in the tank. When a water ring is made to enter the less dense oil, centrifugal force throws out the water, scattering it, and the oil is drawn in to take its place, thus forming a complete oil ring. This ring moving toward the surface of the oil will on reaching the surface be reflected and, re-entering the water, will continue to move as a stable ring of oil. As one of these oil rings is about to break up, the oil of the ring separates into small globules, which are plainly seen whirling in circular orbits about the vortex filament as an axis, in apparent contradiction to the law of centrifugal force.

The fact that liquid vortices react upon each other, and are able to cause motions in solid matter (see View G) before there is actual contact of the vortex with the solid matter, proves that the rings are surrounded by what may properly be termed a "field of fluid motion." This field consists of a system of stream-lines of moving liquid. It may be represented by drawing in the fluid an imaginary system of lines, similar to those employed for representing a magnetic field of force which surrounds a circular conductor carrying an electrical current. About the ring the fluid at any instant has a perfectly definite motion. It is this definite motion of the fluid, outside of the ring, which constitutes the field of fluid motion about the ring, which can react upon a similar field surrounding another ring. If, therefore, at every point in the fluid surrounding the ring lines be drawn in the direction of the motion of the fluid at a given instant, and if at all points in the fluid the number of lines drawn per square centimeter of area, taken normal to the direction of the lines at such points, be made equal in number to the velocity of the fluid, then this system of lines will represent, both in direction and magnitude, the instantaneous fluid motion at every point in the field.

The purpose of this article being only to record experimental results, no mathematical treatment of vortex motions will be attempted. Those interested in this phase of the subject are referred to Chapter VII of Lamb's Hydrodynamics, Third



VIEW J.

Edition. A few physical conceptions may be given here, although these conceptions are confessedly somewhat hypothetical.

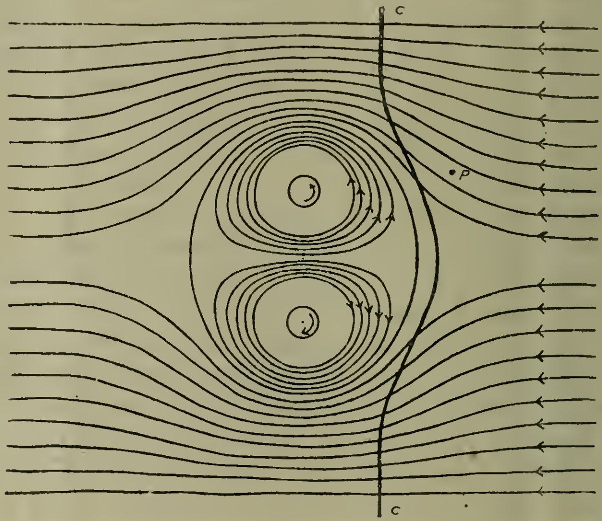
Imagine a circular vortex ring to have for an instant no forward motion. The system of lines drawn to represent the field of motion about the vortex are then assumed to be identical in form and distribution with that which would be required to represent the magnetic field of force about the ring, if it were made to carry an electric current flowing along the filamentary axis and uniformly distributed throughout the cross section of the ring. But all rings, as actually observed, have a rapid forward movement which greatly modifies the distribution of the system of stream-lines as assumed above. In actual rings some of the fluid which surrounds it is carried forward with the ring as it moves through the fluid. The general form of the body of fluid which moves with the ring is that of an oblate spheroid and gives to the ring the mushroom appearance well illustrated in View A. In View I of two rings the color of the upper ring is sufficiently pale so that the true vortex is visible within the spheroidal body of liquid which is moving with it. This spheroidal body of liquid is gradually left behind, in a liquid, like water, having viscosity, and is visible as the trail. As the ring progresses the oblate spheroid of colored liquid becomes gradually replaced by colorless liquid, and when this interchange of colorless liquid for colored is complete the oblate spheroid becomes invisible and the colored vortex only is seen. It then appears as a colored ring, shown in Views C, D, and E. These older rings, in all probability, still carry a body of liquid with them.

This is being drained off and replenished in exactly the same manner as appears in Views A and I.

Diagram, Fig. 13, is constructed on the assumption that the fluid has no viscosity. In it the direction of the lines represents the direction of motion of the fluid, and the density of the lines the velocity of the fluid. This velocity is reckoned in reference to the ring itself; that is, the axes of reference must be considered as having their origin located at the centre of the ring and to move with the ring. The portion of fluid within the two small circles constitutes the true vortex, which retains its color and visibility after the surrounding portion has exchanged all its colored liquid for colorless liquid. The portion of the fluid within the elliptical line, which is a cross section of an oblate spheroid, is the portion of fluid which moves forward with the ring. If the fluid were without viscosity the ring would leave behind it no trail; that is, the same fluid contained in the oblate spheroid with which the ring started on its journey would remain with it to the end. In the actual case this body of fluid is being gradually drained off and replenished until all visibility disappears, except for the vortex itself.

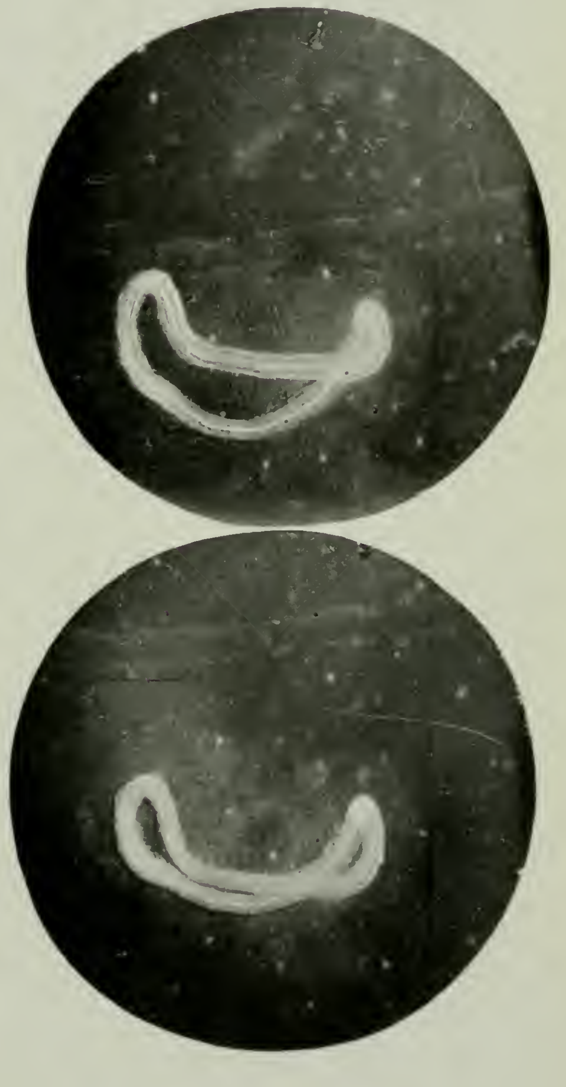
Any small particle, as at *P* (Fig. 13), if more dense than the liquid, is not caught up by the ring when the ring approaches it, but is pushed aside by the body of fluid which the ring carries with it, and receives, when the ring approaches and passes it, a small to-and-fro motion. A cord or chain suspended in the fluid, as indicated by the line *c, c,* is curved forward before it is actually reached by the ring. The View G shows this well.

FIG. 13.



With the above in mind it is not difficult, aided by the photographic views, to explain the union and subsequent double vibratory motions of the rings. For this explanation reference is made to some purely diagrammatic views given below.

In Fig. 14 *a* shows two rings a few centimeters from the gun. They are shown in side view, moving in the direction in-



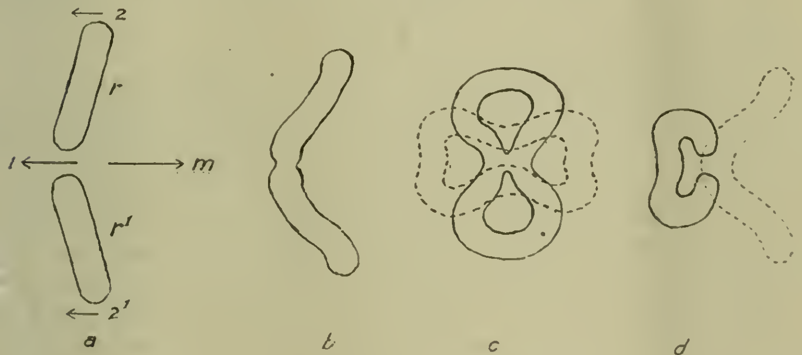
View O.

within the [illegible]

dicated by the arrow, *m*. The velocity of the fluid *in reference to the rings* is indicated at three points by the arrows 1, 2, 2^1. Since this velocity is greater at 1 than at 2 and 2^1, the points on the circumferences of the rings which are adjacent lag behind the points which are opposite, and consequently the planes of the two rings begin to tilt forward in the manner indicated.

Furthermore, as the velocity of the fluid is greater at 1 than at other points equally distant from the filaments of the rings, there will be acting a pressure, according to Bernoulli's principle, which will tend to force together adjacent points of the circumferences of the two rings. Hence, a moment later the rings will assume a position as indicated at *b*. The rings should now be viewed from behind, when their form will be (at a very brief instant later than shown in *b*) as indicated in full line at *c*, or in dotted line at *d*, which is a side view. The high velocity of the fluid at the point of contact has caused the two rings to unite and assume the form of a figure 8, with its upper and lower ends greatly tilted forward in the direction of motion of the now single ring.

FIG. 14.



As this distorted single ring has everywhere an equal tension along its filamentary line, it tends to assume a circular form and lie in a plane normal to the forward direction of motion. But in changing its form to assume the circular plane ring form it overshoots this equilibrium position and assumes, as seen from behind, the form shown in dotted line at *c*, and as seen from the side the form shown at *d* in heavy line. This double oscillation about the form of equilibrium now continues, and the ring advances, its form rapidly changing in the manner which the View P beautifully reveals.

The inquiry naturally arises, Would two rings existing under similar circumstances, in a perfect fluid, or in the luminiferous ether, join together? If two vortices can unite, then would not these in turn join with others? If such be the case for perfect fluids, then it follows that a system of electrons or atoms constituted of vortices, in a perfect fluid, would not preserve their identity, but would form unions which would ultimately destroy any distinctive existence which the vortex atoms or electrons might possess.

These are questions upon which further experimentation would throw much light and the experimental facts obtained would constitute a proper basis for, and check upon, mathematical investigations regarding perfect fluids.

The above-described experiments were begun at the laboratory of The Leeds and Northrup Company, Philadelphia, Pa., in April, 1909, and were later carried on and completed in January, 1911, at the Palmer Physical Laboratory, Princeton, N. J. When working at the first-mentioned place, the writer was ably assisted by Mr. William Wrighton, in charge of the experimental work of The Leeds and Northrup Company, who spent much time on the research, solely for the scientific interest he felt in it. At the latter-mentioned place the writer was much assisted, especially in the photographic work, by Mr. Phillips Thomas. To both of these gentlemen the writer extends his grateful acknowledgments.

Subterranean Wireless Telegraphy. ANON. (*Cosmos.* No. 1369, 423.)—It is announced from Berlin that Dr. Leimbach and Dr. Loewy have transmitted subterranean wireless messages between the potash mines of the Northern Harz, over a distance of about 2½ kilometres, under the ground.

Internal Structure of Pearlitic Steel. M. OKNOF. (*Metallurgie,* viii, 138.)—By photographing the structure of samples of pearlitic steel, and then repeatedly polishing and photographing after each polishing, thus photographing successive layers, it is shown that pearlite is continuous, with the ferrite or cementite distributed through it in grains. This confirms Osmond's "cellular theory" for the structure of steel.

THE HANDLING, TRANSPORTATION AND STORAGE OF PERISHABLE FOODSTUFFS.*

A Review of the Work of the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.

(Contribution from the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.)

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.

PART III.

SELECT METHODS OF ANALYSIS.

THE ANALYSIS OF FLESH 369—THE GENERAL ANALYSIS 370—THE NITROGENOUS CONSTITUENTS OF FLESH 371—REMARKS ON THE DETERMINATION OF NITROGEN BY THE KJELDAHL METHOD 373—THE DETERMINATION OF THE AMMONIACAL NITROGEN IN MEAT 374—CREATINE AND CREATININE 377—MODES OF EXPRESSING NITROGEN RESULTS 378—EXTRACTION OF THE FAT FOR ANALYSIS 378—ANALYSIS OF THE FAT 380—THE ACID VALUE, SAPONIFICATION NUMBER AND THEIR RELATED CONSTANTS 381—THE DETERMINATION OF HYDROXYL GROUPS IN FATS 384—UNSAPONIFIABLE MATTER 385—DETERMINATION OF PHOSPHORUS AND NITROGEN IN FATS 386—DETECTION OF ALDEHYDES AND ACTIVE OXYGEN 388—DETERMINATION OF THE ACID VALUE OF CRUDE FAT 389—DETECTION OF LIPASE 390—THE ANALYSIS OF MILK 390—THE ANALYSIS OF EGGS 396—BIBLIOGRAPHY 396

In the course of the researches which have been carried out in this laboratory, old methods of analysis have been modified and new methods have been devised which are rapid yet very delicate. These methods of chemical analysis have been collected from the original sources and are embodied in the following pages:

THE ANALYSIS OF FLESH.

The chemical analysis of flesh falls into two parts, the general analysis, and the determination of the various nitrogenous constituents. The muscles[1] are separated from the bones, skin, fat and large tendons and are passed through a meat grinder several times—usually three—to obtain a fine division and thorough mixing of the flesh. The removal of the large tendons of chicken muscle does not influence the analytical results, and facilitates the grinding and sampling. The samples for the various determinations should be weighed in tightly stoppered weighing bottles.

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* Presented at the Stated Meeting of the Institute held Wednesday, May 17, 1911.

THE GENERAL ANALYSIS.

In the general analysis [2] determinations are made of the total solids and moisture, fat, ash, protein and creatine. Total solids and moisture are determined by heating 10 grams of meat, in a tared lead bottle cap of two to three inches diameter, at 100° C. in a water-jacketed oven, until the sample ceases to lose weight, and either attains a constant weight or begins to gain in weight.

The fat determination is made upon the dry residue from the total solids and moisture determination. The lead cap and its contents are cut into small pieces, placed in the thimble of a Knorr extraction apparatus, and extracted with ethyl ether, into a tared flask; an electric stove serves as the source of heat. The extraction requires 16 hours, then the ether is evaporated, and the flask and its contents are dried at 100° C. to constant weight or until a gain in weight occurs.

To determine the ash, 2 or 3 grams of meat are dried for several hours at 100° C. in a tared platinum crucible, then incinerated in a muffle until the ash is pure white. Another procedure is to dry and char the meat in the crucible, permit the latter to cool, extract the charred mass with hot water several times, and filter. The insoluble matter and filter paper are reduced to a white ash by ignition over a naked flame, with the aid of ammonium nitrate if necessary. The aqueous extract is now added to the crucible and evaporated to dryness. The crucible and its contents are then ignited in the muffle. A muffle may be prepared from a platinum dish, a piece of platinum foil and asbestos fibres. A thin layer of the fibres is placed on the bottom of the dish, which is heated with the naked gas flame. The crucible rests on the fibres, and the dish is covered with the platinum foil.

The creatine is calculated for the general analysis by multiplying the per cent. of amino acid nitrogen by the factor 3.11.

The protein is calculated by subtracting from the total per cent. of nitrogen in the flesh the per cent. of amino acid nitrogen, and multiplying the remainder by the factor 6.25.

THE NITROGENOUS CONSTITUENTS OF FLESH.

In an analysis of flesh for its nitrogenous constituents the following determinations are made:[3]

Total nitrogen of the flesh.

Total nitrogen of the aqueous extract.

Coagulable nitrogen in the aqueous extract.

Albumose nitrogen.

Amino acid nitrogen.

The total nitrogen of the flesh is determined directly upon the flesh; for the determination of the other constituents, an aqueous extract is prepared. Peptone nitrogen and nitrogen insoluble in water are determined by difference. Frequently direct determinations are also made of the ammoniacal nitrogen, creatine and creatinine.

The total nitrogen of the flesh is determined by the Kjeldahl method upon a two-gram sample of the ground muscle.

For the preparation of the aqueous extract of the flesh, 44 grams of the ground muscle are shaken gently with 300 c.c. of water in a glass bottle, upon a shaking machine, for 15 minutes. If the shaking be too violent an emulsion is formed which cannot be filtered even after the use of a centrifuge. The bottle is then transferred to an electric centrifuge and rotated for 20 minutes to settle the insoluble matter. The solution is filtered through paper, using folded filters. The residue is extracted as before, and extraction is continued until the filtrate no longer responds to the biuret reaction. Thymol should be used during the extraction to inhibit the action of both organized and unorganized ferments. The filtrate is neutralized with N/10 sodium hydroxide solution, using litmus as indicator, and is diluted to 2000 c.c.

To determine the total nitrogen of the aqueous extract, 100 c.c. are placed in a Kjeldahl flask of 500 c.c. capacity, concentrated sulphuric acid is added, and a gentle heat is applied until the water has evaporated; the digestion is then carried out in the usual way.

The nitrogen coagulable by heat, the albumose nitrogen and the amino acid nitrogen are determined on 500 c.c. of the aqueous extract. The coagulation is carried out on an electric stove; if the beaker be placed upon a piece of asbestos board and be covered with a watch glass, coagulation occurs as the solution concentrates. When the volume of the solution has reached 100 c.c., the coagulum is compact, does not adhere to the beaker and may be filtered and washed with ease. Should coagulation be imperfect, the addition of a few drops of very dilute acetic acid will obviate the difficulty. The coagulum is filtered and washed with boiling water until the washings no longer respond to the biuret reaction. The filter and precipitate are transferred to a Kjeldahl flask for digestion.

The filtrate and washings are concentrated to 100 c.c. on the electric stove, then divided into two portions of 50 c.c. each; one portion serves for the albumose determination, the other for the determination of amino acids.

The portion for the determination of albumose nitrogen is evaporated to 30 c.c. in a beaker of 150 c.c. capacity on the electric stove; the beaker is removed from the stove, 1 c.c. of 50 per cent. sulphuric acid is added at once, followed by 40 grams of crystalline zinc sulphate. The solution must be well stirred so that the zinc sulphate will dissolve completely; it is again heated, then allowed to cool and stand for 12 hours to permit separation of the precipitated albumoses. If no crystals of zinc sulphate have separated, more of that salt must be added, the solution again be heated, then permitted to cool in order to insure saturation with the salt at ordinary temperature. The albumoses are collected on a filter in the cold and are washed with a cold, saturated solution of zinc sulphate, faintly acid with sulphuric acid. Filter and precipitate are then subjected to the Kjeldahl method for the determination of nitrogen. This method for the separation and determination of albumoses is based on that of Bömer.[4]

The 50 c.c. portion for the determination of amino acids is transferred to a graduated flask of 100 c.c. capacity, 15 grams of sodium chloride are added, and the flask is placed in an ice box for an hour. Then 30 c.c. of an ice-cold 24 per cent. solution of tannin are added, the flask is filled to the mark with ice-cold distilled water, and the contents are well mixed. The flask and its contents remain in the ice box for 24 hours, then the precipitate is removed by filtration. Unless flask and funnel are kept cold during this operation, re-solution of the precipitate is apt to occur. The nitrogen is determined in 50 c.c. of the filtrate, hence the calculation is made on a sample of 2.75 grams. A blank determination must be made with each experiment, for tannin always contains nitrogen; allowance for the nitrogen content of the blank must be made in the calculation of the amino acid nitrogen. This determination also includes the nitrogen of ammoniacal compounds, *i.e.,* ammonia and amines, if such be present. This method is that of Bigelow and Cook.[5]

From the preceding paragraphs, it follows that the volume of aqueous extract of the flesh used for the determination of the total nitrogen of that extract represents a sample of 2.2 grams of the meat, while the volume used for the determination of the soluble nitrogen coagulable by heat corresponds to a sample of 11 grams of the meat. In like manner, the volume of the filtrate from the coagulum used for the determination of albumoses represents a sample of 5.5 grams of the meat, while the volume of the filtrate from the tannin precipitate used in the determination of amino acid nitrogen corresponds to a sample of 2.75 grams of the meat.

The peptone nitrogen is determined by difference by subtracting from the per cent. of total nitrogen of the aqueous extract the sum of the per cents of coagulable nitrogen, albumose nitrogen and amino acid nitrogen.

The nitrogen insoluble in water is determined by difference by subtracting from the per cent. of total nitrogen in the flesh the per cent. of total nitrogen soluble in water.

Pictures of the shaking machine, centrifuge, and still used in this work were published in Part I of this paper, JOURNAL OF THE FRANKLIN INSTITUTE, 1911, CLXXI, 588–590.

REMARKS ON THE DETERMINATION OF NITROGEN BY THE KJELDAHL METHOD.

The various modifications of the Kjeldahl method have been discussed in a recent paper in this journal.[6] The Gunning modification has been found to be an excellent method for the determination of the nitrogen content of substances of animal origin, and is used in this laboratory several thousand times each year. Kjeldahl flasks of 500 c.c. capacity are used for both digestion and distillation. The sample is digested for 4 hours with 25 c.c. of concentrated sulphuric acid, 10 grams of potassium sulphate, and a small fragment of crystalline cupric sulphate not exceeding 0.2 gram in weight. The digested material is dissolved in

250 c.c. of distilled water; an excess of concentrated sodium hydroxide solution (as a rule 100 c.c.) is poured in so that it sinks beneath the solution, a small quantity of granulated zinc is added, the flask is connected with a safety splash trap or distilling head and a block tin condenser, and the contents are well mixed by shaking. To avoid action of the standard acid on the tin and consequent vitiation of the results, a glass tube is attached to the lower end of the block tin condenser, and dips into the N/10 sulphuric acid which absorbs the ammonia. The distillation is carried out in the usual way and the excess of acid is titrated with N/10 sodium hydroxide, using Congo red as the indicator. A blank determination should be made upon the reagents which usually contain slight but appreciable quantities of nitrogen.

In determining the amino acid nitrogen, 30 c.c. of concentrated sulphuric acid are used; no potassium sulphate is added, for the sodium chloride gives rise to an equivalent quantity of sodium sulphate; until the liberated hydrochloric acid has escaped, a gentle heat must be applied; then the heat should be increased and digestion continued for 5 hours.

Fats and substances rich in fat like egg yolk require a larger quantity of sulphuric acid and a longer period of digestion than do most substances of animal origin. In the digestion of fats, it is prudent to use 800 c.c. Kjeldahl flasks; the digested material may be transferred to a 500 c.c. flask for distillation.

THE DETERMINATION OF THE AMMONIACAL NITROGEN IN MEAT.

Usually the determination is made by subjecting the meat to distillation in the presence of magnesium oxide, and titrating the ammoniacal compounds in the distillate.

Thus Richardson and Scherubel[7] give two methods for the determination of "ammoniacal nitrogen." In their "first method" they distil 25 grams of meat, 10 grams of magnesium oxide and 450 c.c. of water, contained in a litre flask, so that 200 c.c. of distillate collect in from 50 to 60 minutes. The distillate is received in a flask containing N/10 acid, and the excess of acid is determined at the end of the distillation. "Comparable results are obtained in one distillation, but if sufficient water is added to make up the original volume and distillation repeated, more ammonia distils over. After four or five distillations a practical limit is usually reached." In their "second method," they direct that 100 grams of the meat be extracted three times with 150 c.c. of 60 per cent. alcohol; each extract is filtered through cheese-cloth, which is wrung tightly. The three portions of extract are combined, 10 grams of freshly calcined magnesium oxide are added, and the solution is subjected to distillation so that exactly 200 c.c. of distillate collect in 30 minutes; N/10 acid is used as in the preceding method; a blank determination must also be carried out. "Results by this method are usually about one-third to one-half those obtained by the first method."

Richardson and Scherubel state: "We attach considerable importance to the ammoniacal nitrogen determination by both the methods which we have used, although these methods are comparative and not absolute."

The chief fault in the method of Richardson and Scherubel lies in the fact that, although a large portion of the ammoniacal compounds distil during the first period, evolution of these compounds never ceases; thus in a study of hashed fresh meat, these investigators still obtained ammoniacal nitrogen during the tenth period of distillation by their "first method" and during the fourth period of distillation by their "second method."

Pennington and Greenlee[8] attempted to determine the ammoniacal nitrogen in chicken meat according to the "first method" of Richardson and Scherubel; however, the results were far from satisfactory, for ammoniacal nitrogen was obtained in comparatively large quantities during the fourth, fifth and sixth periods of distillation. Thus a fowl kept at 32° F. for 24 hours after slaughter, then analyzed, yielded 0.016 per cent. ammoniacal nitrogen during the fourth period of distillation, and a fowl, which was kept for 48 hours after slaughter at 32° F., then for 72 hours in a cool room, upon analysis yielded 0.016 per cent. ammoniacal nitrogen during the sixth period of distillation. Evidently boiling the flesh with even such a mild alkali as magnesium oxide gives rise to proteolysis and gradual formation of amines or similar nitrogenous compounds, with consequent vitiation of the analytical results.

Therefore the use of magnesium oxide and heat was abandoned, and the method of Folin[9] for the determination of ammonia in the urine and other animal fluids was applied in modified form to flesh analysis. The method depends upon the complete removal of the ammoniacal compounds from the meat by a strong current of air in the cold, in the presence of a mild alkali. The air current is created by a vacuum pump driven by an electric motor. The air passes through sulphuric acid in a wash bottle, which is provided with a safety splash trap such as is used in Kjeldahl distillations, then through a flask which functions as an air trap. "It then passes through a litre flask in which 25 grams of finely-ground meat are suspended in 250 c.c. of water, with 5 grams of magnesium oxide. Between this flask and the 0.1N sulphuric acid absorption bottle is an empty 250 c.c. flask to catch any mechanical spattering or frothing; and beyond the acid bottle a 100 c.c. flask is placed to catch any particles of the acid that may pass into the exit tube. The flasks are set up in batteries of four, using one brass or glass four-way tube to connect with the air pump, and another of similar form leading to the air wash bottle." At the end of the determination the 100 c.c. flask and the tubes connecting it to the absorption flask are washed out into the latter, and the excess of acid is titrated, using Congo red as an indicator. The usual period of aspiration is 5 hours; 2 grams of sodium carbonate may be substituted for the magnesium oxide.

"The addition of about 25 c.c. of alcohol largely prevents the foaming of the protein, which may happen during the latter part of the aspiration period. When once started but little attention is required except an occasional shaking of the flasks. One gram of sodium fluoride, and a temperature of 10–15°, has been found a satisfactory method of preserving unchanged the suspension of meat in water for a period of 24 hours—a fact which is of considerable importance, if many samples are received at one time.

"Like the evolution by distillation with magnesium oxide, the preponderance of ammonia is given off during the first hour, but, unlike that procedure, there is a steady decrease until the zero point is reached."

In certain experiments, the absorption apparatus was changed at intervals; it was thus determined that in from 4 to 6 hours the air current gave rise to a quantitative separation of ammoniacal nitrogen from the flesh of chickens, of which one had been held at 32° F. for 24 hours after killing, another had been kept in a cool room for 6 days, and still another had been kept hard frozen for 2 years. During further aspiration, absolutely no ammoniacal nitrogen was evolved by these samples.

A picture of the apparatus of Pennington and Greenlee appears in Part I of this paper, JOURNAL OF THE FRANKLIN INSTITUTE, 1911, CLXXI, 592.

CREATINE AND CREATININE.

Creatine is methyl guanidine acetic acid, while creatinine is the corresponding anhydride formed by elimination of one molecule of water from one molecule of creatine.

These compounds are determined colorimetrically. According to Folin,[10] " 10 milligrams of creatinine dissolved in 10 c.c. of water give the maximum red color five to ten minutes after addition of 15 c.c. of 1.2 per cent. picric acid solution and 4 to 8 c.c. of 10 per cent. sodium hydroxide. The solution obtained in this way diluted to 500 c.c. gives a liquid of which 8.1 mm. in transmitted light have exactly the same color as 8 mm. of N/2 potassium bichromate solution." The half normal potassium bichromate solution contains 24.54 grams of that salt in one litre of solution. Creatine, on the other hand, does not react with alkaline picric acid solution to form a red color.

In flesh analysis the creatine and creatinine are usually determined together, the creatine being converted into its anhydride during the course of the analysis. Cook[11] has recently studied the factors which influence the creatinine determination. He directs that 25 grams of finely ground meat be shaken with 200 c.c. of water for 1 hour, the extract is decanted and the insoluble residue is shaken for an hour with 200 c.c. of water, then the extract is decanted and the insoluble residue is washed with 50 c.c. of water. In the preparation of this aqueous extract, the shaking machine and the centrifuge are used. The combined extracts and washings are evaporated to a volume of 75 to 100 c.c., then filtered. The filter is washed, and the filtrate and washings are evaporated to a volume of 50 c.c. in a small Erlenmeyer flask, 25 c.c. of normal hydrochloric acid are added, and the flask and its contents are heated in an autoclave for 15 minutes at 117° C., in order to dehydrate the creatine. The solution, which now contains the preformed or original creatinine of the meat plus the creatinine derived from the creatine of the meat by dehydration, is neutralized and evaporated to 50 c.c. Ten c.c. of this solution, equivalent to 5 grams of meat, are mixed with 25 c.c. of 1.2 per cent. picric acid solution and 10 c.c. of 10 per cent. sodium hydroxide solution, let stand for 5 minutes to permit the color to develop, then diluted to 500 c.c., and immediately compared in the Duboscq colorimeter with N/2 potassium bichromate solution, in which the prism is set at 8 mm. From the colorimeter readings, the per cent. of creatinine is calculated by simple proportion.

MODES OF EXPRESSING NITROGEN RESULTS.

Direct analysis gives the percentage of the different nitrogenous constituents present in the sample as prepared for analysis, and makes no allowance for the varying quantities of fat, ash and water which are present in the muscle. In order to compare several samples with respect to their nitrogenous constituents, it becomes necessary to recalculate these results in such a manner that the disturbing factors are eliminated. This object may be attained in two ways, by recalculation to the fat-ash-water-free basis, or by expressing the various forms of nitrogen as per cents of the total nitrogen of the flesh. The results on the fat-ash-water-free basis are of value chiefly in comparing the total amount of nitrogen in the muscle, while the results as per cents of the total nitrogen offer an excellent method for the comparison of the various forms of nitrogen, such as total nitrogen of the extract, albumose nitrogen, etc.

The recalculation to the fat-ash-water-free basis is made by multiplying each form of nitrogen, as determined by analysis, by a factor, which is obtained as follows:

a = Total Solids
b = Fat
c = Ash
x = Factor

$$x = \frac{100}{a-(b+c)}$$

EXTRACTION OF THE FAT FOR ANALYSIS.

In the preparation of chicken fat for analysis,[12] the crude abdominal and subcutaneous fat and the skin are ground in a meat chopper, placed in a thimble, and extracted for two days in a Soxhlet extractor with redistilled petroleum ether of boiling point 40–60° C. The solution of fat is then filtered to remove any solid particles which may have been carried over mechanically from the thimble, the solvent is evaporated on the water bath, and the fat is placed in a vacuum desiccator over calcium chloride to remove the last traces of petroleum ether. Fats should never be placed in a vacuum over concentrated sulphuric acid, for the vapors of the acid will exert a harmful influence on the fat; thus the fat of a perfectly fresh chicken, treated in this way, had the enormously high acid value 44.9. Jannasch[13] states that traces of the vapor of sulphuric anhydride and sulphurous acid may be present in the atmosphere of an ordinary desiccator containing concentrated sulphuric acid. Of course, in a vacuum the quantity of these vapors would be much greater.

The extraction of fat from egg yolk[14] is a more difficult task. Since the yolk contains about 50 per cent. of water, it is necessary to dehydrate the yolk before extracting the fat. The dehydration is carried out by means of alcohol. The yolks of a number of eggs are mixed by stirring, then slowly poured, with constant stirring, into several times their volume of alcohol. The coagulated material is collected upon a filter, and extracted for two days with alcohol in a Soxhlet extractor. The filtrate and extract are combined and distilled on a water bath in vacuum. The residue from the distillation is taken up in redistilled petroleum ether, which is then used for the fat extraction. The coagulated yolk, after having been extracted with alcohol, is ground in a meat chopper, and placed over calcium chloride in a vacuum desiccator in order to remove the last traces of alcohol. The ground material is then extracted with redistilled petroleum ether in the usual way, in a Soxhlet extractor.

Butter fat may be extracted from cream in the same manner as fat is extracted from egg yolk.

If ethyl ether be substituted for petroleum ether, the fat constants will be influenced in value by the change of solvent. This fact is made clear by the following experiments in which the crude abdominal fat of chickens was divided into two portions, of which the one was extracted with ethyl ether, the other with redistilled petroleum ether.

Sample Number	352		353	
Solvent	Ethyl Ether	Petroleum Ether	Ethyl Ether	Petroleum Ether
Iodine Number	75.4	75.0	70.7	70.0
Acid Value	1.7	1.8	1.6	1.5
Saponification Number	197.2	194.4	195.2	188.2
Ester Value	195.5	192.6	193.6	186.7
Hehner Number	96.41	94.27	96.51	93.49

ANALYSIS OF THE FAT.

In the course of the analysis of a fat in this laboratory any or all of the following determinations may be made:

Specific Gravity.
Index of Refraction.
Viscosity.
Iodine Number.
Reichert-Meissl Number.
Acid Value.
Saponification Number.
Ester Value.
Soluble Acids.
Hehner Number.
Acetyl Value.
Acetyl Saponification Number.
Lactones.
Unsaponifiable Matter.
Phosphorus Content.
Nitrogen Content.
Aldehydes.
Active Oxygen.

Certain of these determinations are so well known that they need not be described in detail. The specific gravity is usually obtained by means of a pyknometer. The index of refraction is determined with a water-jacketed Abbé refractometer,[15] the viscosity by means of a torsion viscosimeter.

The iodine number is determined by the method of Hanus [16] as modified by the Association of Official Agricultural Chemists.[17] The determination of the Reichert-Meissl number is carried out according to the method of Leffmann and Beam.[18]

THE ACID VALUE, SAPONIFICATION NUMBER AND THEIR RELATED CONSTANTS.

The most convenient and accurate method for the determination of the acid value is based on the use of alcohol[19] as a solvent. From 5 to 20 grams of fat are weighed out in a tared flask, 50 c.c. of previously neutralized 95 per cent. alcohol are added and the flask is heated on an electric stove until the alcohol boils vigorously; the free fatty acids pass into solution in the boiling alcohol and are immediately titrated with N/10 sodium hydroxide, using phenolphthalein as an indicator.

By another method,[12] the fat is weighed out in a tared flask, 100 c.c. of a 15 per cent. solution of sodium chloride are added, the flask is immersed in hot water until the fat is liquefied, then the free acids are titrated with N/10 sodium hydroxide, phenolphthalein serving as the indicator; the flask must be shaken frequently and vigorously until a distinct pink color appears. If the fat has a high acidity, the sodium chloride salts out the soap formed in the titration, and this hard soap encloses the fat and fatty acids and thus interferes with the titration; the difficulty may be overcome by use of a 15 per cent. solution of potassium chloride, for soft soaps do not exert such a harmful influence on the titration. This method can be used only with oils and fats of low melting point. Fats which have a fairly high melting point, *e.g.*, egg fat, solidify during the titration, enclose free fatty acid and give too low a result. This is shown by the following determination of the acid value of the same egg fat by the two methods:

Method	Acid Value
By potassium chloride	2.7
By ethyl alcohol	5.8

The alcohol method, on the whole, is far superior to the alkali chloride methods.

The saponification number is determined by saponifying 5 grams of fat in a tared flask by means of 50 c.c. of a 4 per cent. solution of potassium hydroxide in redistilled, aldehyde-free alcohol.[20] The saponification is carried out on an electric stove. A blank determination is carried out, and, after the flasks and their contents have cooled, both determination proper and blank are titrated with N/2 hydrochloric acid, using phenolphthalein as indicator. The difference between the number of c.c. of standard acid required to neutralize the blank and to neutralize the determination proper are a measure of the quantity of potassium hydroxide required to saponify the sample of fat, hence the saponification number may then be calculated.

In determining the saponification number of dark fats the end point of the final titration, although definite, is at times quite difficult to recognize. In order to overcome this difficulty, the suggestion[21] has been made that for phenolphthalein be substituted the indicator known as alkali blue 6B, which is blue with acids and red with alkalies and is sensitive to fatty acids. Two c.c. of a two per cent. solution of the indicator in alcohol are used in each titration. In titrating egg fat saponification numbers with alkali blue 6B, the writer has found the end point to be modified to green, due doubtless to the chromogenic matters of the fat; the end point, however, is quite definite.

Stiepel[22] has devised the following procedure for determining the saponification number of dark fats and oils. Five grams of fat are saponified in the usual way with alcoholic potash, barium chloride is added—20 c.c. of a normal solution should suffice—then 300 to 400 c.c. of recently boiled water. The flask is heated for 30 minutes beneath a reflux condenser to exclude carbon dioxide; the barium soaps are precipitated and carry down with them all the coloring matters. The excess of alkali may then be titrated with N/2 hydrochloric acid in the supernatant liquid; or if the precipitate make difficult the recognition of the end point, it may be removed by filtration and the titration be made on an aliquot portion of the filtrate. Phenolphthalein is used as an indicator.

These three methods give almost the same value for the saponification number, as is shown by the following results which were obtained upon the same egg fat:

Method.	Saponification Number.
Titration with phenolphthalein	190.1
Titration with alkali blue 6B	188.4
Barium chloride precipitation	187.5

The ester value is usually determined by subtracting the acid value from the saponification number. However, at times the small quantity of material at the disposal of the analyst compels the direct determination of the acid value and ester value upon the same sample, and calculation of the saponification number by addition of the two constants directly determined. The free acids are titrated by the alcohol method and the acid value is calculated; then alcoholic potash is added and the neutral esters are saponified, a blank determination is carried out, both determination proper and blank are titrated, and the ester value is calculated. By addition of acid value and ester value, the saponification number is obtained.

From the saponification number may be calculated the mean molecular weight of a fat, and the mean number of carbon atoms in the fatty acid molecule. The latter calculation is based on the assumption that the fat is a neutral, saturated triglyceride; the presence of free fatty acid, of unsaturated acids and of unsaponifiable matter is disregarded; however, the presence of these compounds would tend to give a higher value for the number of carbon atoms in the fatty acid molecule.

Let x equal the mean molecular weight of the fat, and y the saponification number.

$$\begin{aligned} \text{Fat} : 3\ \text{KOH} &= \text{Weight fat} : \text{Weight KOH} \\ x : 3\,(56.11) &= 1 : 0.001y \\ x &= \frac{168.33}{0.001y} \end{aligned}$$

The triglyceride of a saturated fatty acid has the general formula $(C_nH_{2n-1}O_2)_3C_3H_5$; equating this formula to the mean molecular weight and substituting for carbon, hydrogen and oxygen their respective atomic weights, it follows that

$$3(12n + 2n - 1 + 32) + 36 + 5 = X.$$

Solving for n, the number of carbon atoms in the fatty acid molecule,

$$n = \frac{x - 134}{42}$$

The determination of the soluble acids and of the insoluble acids (Hehner number) is usually combined with that of the saponification number,[20] according to the official method of the Association of Official Agricultural Chemists, to which reference must be made for the details of the procedure.

In determining the acid value and saponification number, Erlenmeyer flasks of 300 c.c. capacity are most convenient.

THE DETERMINATION OF HYDROXYL GROUPS IN FATS.

From a study of certain constants of a pure fat or oil and of the same fat after acetylation, the presence of hydroxyl groups may be detected. These hydroxyl groups are usually present as hydroxy acids, *e.g.*, in castor oil, but may also occur as free alcohol groups, either in mono- and diglycerides or in the aromatic alcohols cholesterol and phytosterol. The saponification number of the acetylated fat is termed the acetyl saponification number. If the acetyl saponification number be higher than the saponification number proper, then hydroxyl groups are present in the fat, and have been converted into acetyl groups during the process of acetylation.

The acetyl number is a measure of the hydroxyl groups. The determination of this constant may be made with accuracy in a short time by the filtration method of Lewkowitsch.[23] Five grams of the acetylated fat are saponified with an accurately measured quantity of standardized alcoholic potash. The alcohol is evaporated, the soap is dissolved in water, a known excess of standardized sulphuric acid is added, the flask is heated gently beneath a reflux condenser until the insoluble acids form an oily layer, they are then removed by filtration and washed until the washings are no longer acid. The filtrate and washings are combined and titrated with N/10 sodium hydroxide, using phenolphthalein as indicator. The result is expressed as acetyl number, *i.e.*, "the number of milligrams of caustic potash (KOH) required for the neutralization of the acetic acid obtained on saponifying one gram of the acetylated fat or wax." After allowing for the known excess of mineral acid, the number of cubic centimeters of N/10 sodium hydroxide is multiplied by 5.611 and divided by the weight of the acetylated fat; the result is the acetyl value. Lewkowitsch [24] terms the value thus obtained the "apparent acetyl value;" he determines in like manner the quantity of potassium hydroxide required to saturate the volatile acids of the original fat, subtracts this from the apparent value and thus obtains the "true acetyl value" which is the correct measure of the hydroxyl groups.

If the insoluble fatty acids of a fat or oil be isolated and their saponification number and acid value be determined, at times the saponification number will be found to be higher than the acid value, although one would expect the two constants to be the same. This difference between the two constants is due to the presence of lactones in the free acids [25] and therefore indicates the presence of hydroxy acids in the fat. Lactones are not neutralized during the titration in the determination of the acid value; but the lactonic ring is opened by the boiling alcoholic potash during the determination of the saponification number, and the hydroxy acids thus formed are neutralized by the alkali, and thus cause the saponification number to be higher than the acid value.

The following data obtained by the analysis of fat from fresh chickens, laboratory number 340, are concrete examples of the facts just enumerated. The presence of hydroxyl groups —hydroxy acids—is shown (1) by the fact that the acetyl saponification number is higher than the saponification number of the fat, (2) by the acetyl value, and (3) by the saponification number of the insoluble fatty acids, which is higher than their acid value.

Saponification number of the fat	196.2
Acetyl saponification number of the fat	200.6
Acetyl value of the fat	7.4
Acid value of the insoluble acids	187.2
Saponification number of the insoluble acids	198.9

UNSAPONIFIABLE MATTER.

The following method for the determination of the unsaponifiable matter in a fat has proved satisfactory. Ten grams of fat are saponified by boiling with alcoholic potash beneath a reflux condenser. The resulting solution is transferred to a casserole, while hot; five grams of sodium bicarbonate and about one hundred grams of sand (previously ignited and allowed to cool) are added, the solution is evaporated to dryness on the water bath, then heated for several hours in the water-oven to insure complete dryness. The resulting mass is ground in a mortar, then placed in the thimble of a Soxhlet extractor and extracted with ethyl ether into a tared flask. The extraction requires two days. The mortar and casserole are washed with ethyl ether, which then is filtered and added to the extract in the tared flask. The ether is evaporated and the flask and its contents are dried in the water-oven until the weight either becomes constant or increases. The quantity of unsaponifiable matter is then calculated. The ether must be redistilled over sodium.

If it be desired to investigate the nature of the unsaponifiable matter, a larger sample of fat should be used. To separate the cholesterol from the unsaponifiable matter of egg fat, clarification by means of purified animal charcoal, and recrystallization from methyl alcohol according to Cappenberg[26] form an excellent procedure. Cappenberg dissolves the material in hot methyl alcohol, filters while hot, adds 20 per cent. of water, concentrates until crystallization begins, then cools to 0° C., whereupon all the cholesterol crystallizes out. The precipitate is collected on a filter and washed first with 50 per cent. methyl alcohol, then with hot water. Cholesterol may be identified by its crystalline form, or, according to Bömer,[27] by the melting point of its acetate.

DETERMINATION OF PHOSPHORUS AND NITROGEN IN FATS.

In order to determine the phosphorus content of a fat, it is first necessary to destroy the organic matter; this may be done by digestion with sulphuric acid or by combustion with sodium peroxide. If the former procedure[28] be chosen, the weighed sample of fat is digested in a Kjeldahl flask with concentrated sulphuric acid and potassium sulphate until the contents of the flask are perfectly clear and colorless. Addition of a small fragment of cupric sulphate will hasten the digestion. The digested material is dissolved in water, transferred to a beaker, made alkaline with ammonia, then acid with nitric acid; fifteen grams of ammonium nitrate are added to the hot solution, followed by 50 c.c. of the official ammonium molybdate solution for each decigram of phosphoric oxide which may be present. The beaker and its contents are permitted to stand over night in a warm room to insure complete precipitation of the ammonium phosphomolybdate. The precipitate is collected upon a filter, washed with 10 per cent. ammonium nitrate solution, then dissolved off the filter by means of ammonium hydroxide and hot water; the volume of the solution thus obtained should not exceed 100 c.c. The solution is almost neutralized with hydrochloric acid and permitted to cool to room temperature. Fifteen c.c. of official magnesia mixture, for each decigram of phosphoric oxide which may be present, are added drop by drop, followed after a period of fifteen minutes by 12 c.c. of concentrated ammonia. The precipitate of ammonium magnesium phosphate is permitted to stand over night, then collected on a tared Gooch crucible, washed with 2.5 per cent. ammonia, ignited in a muffle to magnesium pyrophosphate and weighed.

A modification of the sodium peroxide combustion method of LeClerc and Dubois [29] may be used to determine the phosphorus content of a fat. The weighed sample of fat is first saponified in the nickel crucible by heating with 5 grams of anhydrous sodium carbonate and sufficient water. The crucible is then allowed to cool, and the combustion is carried out as directed by Dubois.[30] The fused mass is dissolved in hot water, and the solution is acidulated with nitric acid. The phosphoric acid is precipitated as ammonium phosphomolybdate and finally weighed as magnesium pyrophosphate.

Of the two methods, digestion with sulphuric acid permits the use of a larger sample, and also requires less attention than the combustion with sodium peroxide.

The writer prefers the gravimetric method for the determination of sulphuric acid; however, should it be desired to use the volumetric method [31] (solution of the ammonium phosphomolybdate in a known volume of standard fixed alkali hydroxide, and titration of the excess of alkali with standard mineral acid, using phenolphthalein as an indicator) in connection with the sodium peroxide combustion, it is essential that the directions for precipitation, according to the volumetric method, be followed in every detail, on account of the influence of the conditions of formation upon the constitution of ammonium phosphomolybdate. Thus Gillan,[32] who has recently made a study of this complex salt, reaches the conclusion " that the conditions of formation largely determine the constitution of the salt, and it is evident that to get a constant ratio for the acid content it is necessary to work under very definite conditions as to quantity of material present, and as to the dilution of the solution in which the complex salt is formed." Wherry[33] has suggested that the complex inorganic acids and their salts are not true chemical compounds, but partake rather of the nature of the so-called "absorption compounds."

The determination of the nitrogen content of fat has already been described in the chapter upon the determination of nitrogen by the Kjeldahl method.

DETECTION OF ALDEHYDES AND ACTIVE OXYGEN.

The literature upon the occurrence of aldehydes and active oxygen in fats and oils, which have been exposed to the action of the forces of Nature, has been reviewed in a previous contribution from this laboratory.[34] It will therefore suffice to state that the following methods have been tried and found to be of value in detecting these compounds in such fats.

Aldehydes frequently occur in both crude and extracted fats which have been exposed to the action of the air for some time. They may be detected by means of fuchsin sulphurous acid[35] which is prepared by mixing the following reagents in the given order:

30 c.c. of an 0.1 per cent. solution of fuchsin.
20 c.c. of sodium bisulphite solution of 34° Baumé.
200 c.c. of water.
3 c.c. of sulphuric acid of 66° Baumé.

Ten c.c. of the reagent and 2 c.c. of the molten extracted fat are mixed and well shaken; the maximum color develops within half an hour. After the fat and the aqueous layer have separated on standing, the violet color appears in the fat. Occasionally the aqueous layer also assumes a violet tint.

The test may also be applied to finely divided crude fat. Several grams of the fat are placed in a test tube, which is immersed in warm water to render the fat, then is permitted to cool to room temperature. Ten c.c. of the reagent are added and the experiment is carried out as with extracted fats.

Active oxygen may be detected in fats by Legler's test or by Walker's test. Legler[36] recommends that 10 c.c. of water be warmed in a test tube, an equal volume of the molten fat be added, then several drops of a solution of neutral lead acetate and of ammonia water. The mixture is shaken vigorously. If active oxygen be present, the mixture is colored from a pale yellow to a deep orange-brown, due to the formation of hydrated lead peroxide; the intensity of the color depends on the quantity of active oxygen present in the fat.

Walker's test [37] for active oxygen is based upon the liberation of iodine from potassium iodide by active oxygen in the presence of acetic acid. This test exists in two modifications. Potassium iodide-starch paper is saturated with the fat, a drop of 10 per cent. acetic acid is placed on the paper, which is covered with a bell jar to exclude laboratory fumes; if active oxygen be present a blue ring forms about the acetic acid in the course of one to five hours. Or 5 c.c. of molten fat are shaken with a solution of 5 c.c. of glacial acetic acid and 1 gram of potassium iodide in 50 c.c. of water. In the course of an hour, the active oxygen—if present—will liberate iodine and thus cause the solution to assume a yellow color. The addition of a few drops of starch paste before shaking increases the delicacy of the test, for the blue color of starch iodide is easier to recognize than the yellow color of an aqueous iodine solution. The fat should be melted for these tests at as low a temperature as possible, since heat tends to destroy the peroxides which respond to these reagents. In both modifications of Walker's test, a blank experiment should always be made as a control upon the reagents.

The writer has detected the presence of active oxygen in samples of extracted chicken fat which had been exposed to the action of the air for several months.

DETERMINATION OF THE ACID VALUE OF CRUDE FAT.[38]

In this laboratory the abdominal or gizzard fat of chickens has generally been studied, although the subcutaneous fat has at times been used. The crude fat is passed through a meat chopper several times. Ten grams of the sample are weighed out in a tared Erlenmeyer flask of 250 c.c. capacity; 50 c.c. of alcohol, previously neutralized, are added; and the flask is heated on an electric stove until the alcohol boils briskly. The free fatty acids dissolve in the hot alcohol and are titrated at once with N/10 sodium hydroxide, shaking vigorously. Phenolphthalein is used as an indicator; the end point is shown by a faint pink color, persisting for fifteen seconds.

DETECTION OF LIPASE.[39]

A known quantity of crude fat is ground in a mortar with sand, which has been ignited and permitted to cool to the temperature of the room, then is extracted with ten times its weight of distilled water. The extract is poured through a strainer of wire gauze, then filtered through absorbent cotton. Fifty c.c. of the extract thus prepared are mixed with 1 c.c. of an ester, 1 c.c. of toluol and 0.2 c.c. of a 1 per cent. solution of phenolphthalein in alcohol. The esters more commonly used are ethyl butyrate and amyl salicylate, although many other esters have also been utilized for this purpose. The mixture is made neutral by means of N/10 sodium hydroxide solution. At the same time a blank is prepared by boiling 50 c.c. of the extract, permitting to cool to the temperature of the room, then adding the reagents and neutralizing. Boiling the blank destroys both organized ferments (bacteria, moulds and yeasts) and unorganized ferments (enzymes). In the determination proper, the toluol inhibits the action of organized ferments, but permits the enzymes to react. Both determination and blank are placed in an incubator at 40° C., the optimum temperature for lipase.[40] After the lapse of one or more days, they are again titrated; if the determination proper contain more free acid than the blank, that acid has been liberated from the ester by the lipase, and therefore proves the presence of that enzyme in the crude fat. If necessary, more toluol may be added during the lipolysis to replace that lost by evaporation.

THE ANALYSIS OF MILK.

The methods for the determination in milk of such constituents as total solids, fat, ash and lactose are described in detail in the methods of analysis of the Association of Official Agricultural Chemists[41] and in the various text-books, therefore only certain phases of milk analysis will be discussed in this paper, including the determination of the various nitrogenous compounds, of the lecithin and of the fat by the Roese-Gottlieb method.

The technic for the quantitative determination of the total nitrogen in milk, and of its distribution as casein, albumin and syntonin, caseose, amino acid and ammoniacal nitrogen has been studied in detail in this laboratory.[42] The determination of the total nitrogen is made upon 5 grams of the milk by the Kjeldahl method as directed by Van Slyke and Hart.[43]

The casein nitrogen is likewise determined by the method of Van Slyke and Hart: [43]

"To about 10 grams add 90 c.c. of water at 104° F. to 108° F. (40° C. to 42° C.) and then 1.5 c.c. of 10 per cent. acetic acid. Agitate and warm at the temperature given above until a flocculent precipitate separates, leaving a clear supernatant liquid. Filter, wash and treat by the Kjeldahl method for estimating nitrogen.

"The use of acetic or any other acid in precipitating casein in milk, whose casein has been digested in any degree, precipitates, in addition to casein, any paranuclein that is present. We have not yet succeeded in devising satisfactory methods for the separation of these compounds." [43]

When milk is kept at low temperatures, the acidity increases and after several weeks is much higher than is required to produce a curd spontaneously at ordinary temperatures, yet the phenomenon of curdling rarely occurs. Such milk must first be made neutral to phenolphthalein by addition of fixed alkaline hydroxide; the casein is then determined in the usual way. The precipitation is best carried out by diluting the milk in a beaker with water of a temperature of 40–42° C., then placing the beaker in a bath of water of that temperature, adding the acetic acid with stirring, and finally filtering as soon as the precipitate is flocculent and the supernatant liquid is clear.

The precipitate of casein is washed with water of a temperature of 40° C., until the washings fail to respond to the biuret test. The albumin and syntonin nitrogen are determined in the combined filtrate and washings from the casein determination by the provisional method of the Association of Official Agricultural Chemists.[41] The solution is neutralized with sodium hydroxide, using phenolphthalein as an indicator, 0.3 c.c. of a 10 per cent. solution of acetic acid are added, the beaker and its contents are placed on an electric stove, the solution is evaporated to a small volume in order to insure complete coagulation of the albumin and syntonin. The precipitate is collected on a filter and washed with boiling water until the washings no longer respond to the biuret test. The filter and precipitate are transferred to a Kjeldahl flask, and the nitrogen is determined.

The quantity of protein, casein and albumin is calculated by multiplying the total nitrogen of the milk, the casein nitrogen and the albumin nitrogen respectively by the factor 6.38.[41]

The filtrate and washings from the albumin and syntonin are used for the determination of caseose nitrogen. They are combined and evaporated on an electric stove to a volume of 30 c.c., 1 c.c. of 50 per cent. sulphuric acid is added, and the caseoses are precipitated by means of zinc sulphate and determined in exactly the same manner as the albumose nitrogen of flesh was determined (see page 372 for the details of the procedure).

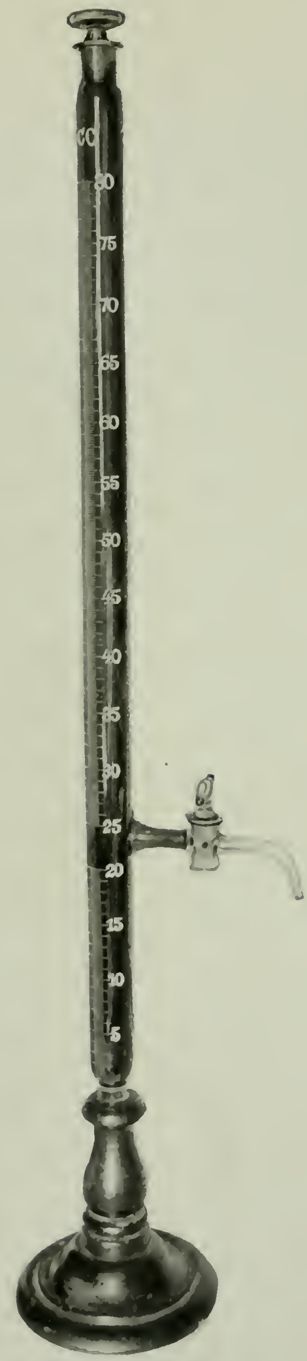
The method for the determination of the amino acid nitrogen is that of Bigelow and Cook.[5] Ten grams of milk are placed in a graduated flask of 100 c.c. capacity, 15 grams of sodium chloride are added, and the flask is placed in an ice box for an hour. Thirty c.c. of an ice-cold 24 per cent. tannin solution are added, the flask is filled to the mark with ice-cold distilled water, and the contents are well mixed. The flask and its contents are kept in the ice-box for 24 hours, then the precipitate is removed by filtration. Both flask and funnel are kept cold during this operation to prevent re-solution of the precipitate. The nitrogen is determined by the Kjeldahl method in 50 c.c. of the filtrate, hence the calculation is made on a sample of 5 grams. A blank determination is also carried out, and due allowance for the nitrogen content of the blank is made in the calculation of the amino acid nitrogen.

The ammoniacal nitrogen in milk is determined by the method of Berg and Sherman [44] with slight modifications. Fifty grams of milk are mixed with 10 grams of sodium chloride, 0.5 gram of sodium carbonate and 50 c.c. of neutral methyl alcohol, in a round-bottomed flask of 2000 c.c. capacity. The flask is provided with a rubber stopper through which pass a distilling head, such as is used in Kjeldahl distillations, and an inlet-tube, which serves to admit air at the end of the distillation. Rubber tubing is attached to the upper end of the inlet-tube and is closed by a screw clamp. A thermometer is suspended from the rubber stopper by means of platinum wire. The bulb of the thermometer and the lower end of the inlet-tube are beneath the level of the liquid in the flask. The distilling head is connected to a series of three Drechsel bottles, which are surrounded by ice-water. Ten c.c. of N/10 sulphuric acid, diluted to 20 c.c. with distilled water, are placed in each of the two Drechsel bottles adjacent to the distilling head, while the third bottle serves as a trap and is connected with the vacuum system of the laboratory. All connections by means of rubber tubing are tightly wired. The vacuum pump is started and the flask is placed in a water bath, which has a temperature of 60–65° C. The temperature of the bath is so regulated that the temperature of the liquid within the flask does not rise above 62° C. The sodium carbonate liberates the ammonia from ammonium salts, while the sodium chloride by reducing the hydrolytic dissociation of the carbonate prevents or at least renders "less likely the cleavage of ammonia from organic matter." The methyl alcohol also tends to prevent cleavage by lessening the dissociation of the carbonate and by lowering the boiling point of the liquid. The liberated ammonia distils over and is absorbed by the sulphuric acid in the Drechsel bottles. A low vacuum is used at the start of the distillation and is gradually increased. A period of 15 to 30 minutes is required for the distillation, the end of which is made known by a distinct tendency for the contents of the Drechsel bottles to "suck back." The vacuum cock is then closed, the screw clamp on the inlet-tube is opened at the same time, and air is admitted in such a manner that the distillate is not forced into either the distilling flask or the trap bottle, but remains in its containers. When atmospheric pressure has been restored throughout the apparatus, the distillate is poured into a beaker, the three Drechsel bottles and their connecting tubes are washed with distilled water and the washings are added to the beaker; the solution is diluted to 250 c.c., and the excess of acid is determined by titration with N/10 sodium hydroxide, using cochineal as an indicator. A blank experiment is made upon the reagents, and due allowance is made for the ammoniacal nitrogen content of the blank in calculating the free ammoniacal nitrogen of the milk.

Berg and Sherman state that fresh milk yields the same per cent. of ammoniacal nitrogen, whether sodium chloride be added to or omitted from the contents of the distillation flask. However, after milk has become stale, a higher per cent. of ammoniacal nitrogen is obtained by distilling milk in vacuo at the above temperature with methyl alcohol and sodium carbonate than is obtained by distilling under the same conditions of temperature and vacuum with these reagents plus sodium chloride. The term free ammoniacal nitrogen is applied to the ammoniacal nitrogen liberated on distillation in the presence of sodium chloride, while the term cleavage ammoniacal nitrogen is applied to the per cent. of nitrogen which remains after the per cent. of free ammoniacal nitrogen is subtracted from the per cent. of total ammoniacal nitrogen obtained by distillation without the use of sodium chloride. If the analytic results be expressed as percentages of ammonia, these terms become free ammonia and cleavage ammonia respectively. Fresh milk contains only free ammoniacal nitrogen, while stale milk contains not only free ammoniacal nitrogen but also certain nitrogenous organic compounds from which cleavage ammoniacal nitrogen is split off during the distillation in the absence of sodium chloride.

The method of Nerking and Haensel [45] in a slightly modified form serves for the determination of the lecithin content of milk and cream. One hundred grams of milk or 25 grams of cream are added to 200 c.c. of alcohol; the mixture is stirred well; after the precipitate has settled, it is removed by filtration. The filter and precipitate are placed in the thimble of a Soxhlet apparatus and extracted for at least 30 hours with chloroform. The alcoholic filtrate is evaporated in vacuo on a water bath at a temperature of 50° to 60° C.; the residue is exhausted by extraction with chloroform, and the extract is added to that obtained from the precipitate. The chloroform solution is transferred either to a nickel crucible or to a Kjeldahl flask and is evaporated to dryness on the water bath; the residue in the crucible is burned with sodium peroxide, while the residue in the flask is digested with sulphuric acid. The details of both methods of procedure are given in the chapter on the determination of phosphorus in fats. The phosphoric acid thus obtained is finally weighed as magnesium pyrophosphate, and the per cent. of phosphoric oxide present as lecithin is calculated; or the per cent. of lecithin itself may be calculated.

The Röhrig tube [46] used in determining fat in milk by the Gottlieb-Röse method is shown in the figure. Ten grams of milk are placed in the tube, and shaken with 1 c.c. of concentrated ammonia water, 10 c.c. of 92 per cent. alcohol are added, the contents of the tube are again shaken, then let stand for a few minutes. Thirty c.c. of ethyl ether are added and the contents



Röhrig tube.

of the tube are mixed by shaking thoroughly for one minute, then 30 c.c. of redistilled petroleum ether of boiling point 40–60° C. are added and the tube is again shaken thoroughly. The liquid is then permitted to separate into two layers. The supernatant liquid, which is a mixture of the two ethers containing the butter fat in solution, is drawn off as completely as possible and permitted to run through a small filter paper into a small tared Erlenmeyer flask; the filter is washed with a mixture of equal volumes of the two ethers. The residual liquid in the tube is extracted as before by adding 30 c.c. of ethyl ether, shaking, adding 30 c.c. of the redistilled petroleum ether, shaking and permitting to separate into two layers. The total volume of the upper layer is noted, and it is drawn off as completely as possible into a second tared flask, filtering as before; the volume thus drawn off is also noted. The two flasks are heated cautiously on the water bath until the solvent has been driven off, then are heated in the water oven at 100° C. until a gain in weight occurs; after each period of heating for 30 minutes the flasks are placed in a desiccator, permitted to cool, and weighed.

It is evident that the mixture of the two ethers which remains in the tube at the end of the second extraction contains butter fat, and that the weight of this fat must be considered in calculating the per cent. of fat in the milk. Hence the weight of fat in the tared flask used in the second extraction is multiplied by the total volume of the second extract, and the product is divided by the volume of that extract which was drawn off; the result is the total weight of fat in the second extract. The total weight of fat in the milk is the sum of the weight thus calculated and the weight of the fat obtained in the first extraction. The per cent. of fat is readily calculated by multiplying the total weight of the fat by 100, and dividing by the weight of milk taken as a sample. This method may be applied to cow's milk and breast milk, and, in modified form,[47] to condensed and evaporated milk, ice cream, milk powder and cheese.

It may be mentioned that, after milk has been clarified in the usual way by means of cupric sulphate and sodium hydroxide,[48] the lactose may be determined by the method of Munson and Walker.[49]

THE ANALYSIS OF EGGS.

The method of separation of the white and yolk of raw eggs for chemical examination has been described in the chapter entitled "Studies of Eggs," in Part II. The methods for the general analysis are quite similar to the methods used in flesh analysis, which have been described in full in the preceding pages. However, only five grams of yolk are taken as a sample for the determination of total solids, moisture, and fat (ether extract); if a larger sample be taken, the thimble of the Knorr extractor is too small to hold the total solids plus the lead dish during the extraction with ethyl ether in the determination of the ether extract. The white is well mixed by passing it several times through a Buchner funnel. The methods for the separation of the various forms of nitrogen in the white are likewise similar to those used in flesh analysis; for the details of the procedure, the original paper of Pennington[14] should be consulted. The mode of extracting the fat from the yolk is given in detail on page 379; the methods of determining the fat constants have also been given in the preceding pages.

The writer desires to acknowledge his indebtedness to Dr. M. E. Pennington and to Dr. E. Q. St. John for assistance and valuable suggestions in the preparation of this paper.

BIBLIOGRAPHY.

[1] Pennington: U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 115, 62, 1908.
[2] Pennington: Bureau of Chemistry Bulletin No. 115, 63, 1908.
[3] Pennington: Bureau of Chemistry Bulletin No. 115, 64, 1908.
[4] Bömer: Zeitschrift für analytische Chemie, 1895, xxxiv, 562.
[5] Bigelow and Cook: Journal of the American Chemical Society 1906, xxviii, 1485.
[6] Hepburn: Journal of the Franklin Institute 1908, clxvi, 81.
[7] Richardson and Scherubel: Journal of the American Chemical Society 1908, xxx, 1515.
[8] Pennington and Greenlee: Journal of the American Chemical Society 1910, xxxii, 561.
[9] Folin: Zeitschrift für physiologische Chemie 1902–1903, xxxvii, 161.
[10] Folin: Zeitschrift für physiologische Chemie 1904, xli, 223.
[11] Cook: Journal of the American Chemical Society 1909, xxxi, 673.
[12] Pennington: U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 115, 66, 1908.
[13] Jannasch: Praktische Leitfaden der Gewichtsanalyse. Zweite Auflage. Leipzig. Veit & Comp. 1904, 1.

[14] Pennington: Journal of Biological Chemistry 1910, vii, 109.

[15] Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists. U. S. Department of Agriculture. Bureau of Chemistry Bulletin No. 107 revised, 1910, 132.

[16] Hanus: Zeitschrift für Untersuchung der Nahrungs- und Genussmittel 1901, iv, 913.

[17] U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 107 revised, 1910, 136.

[18] Leffmann and Beam: Analyst 1891, xvi, 153; Leffmann and Beam, Select Methods of Food Analysis, 2nd Edition, 1906, 143; Bureau of Chemistry Bulletin No. 107 revised, 1910, 141.

[19] Bureau of Chemistry Bulletin No. 107 revised, 1910, 142.

[20] Bureau of Chemistry Bulletin No. 107 revised, 1910, 137.

[21] Mitchell: Allen's Commercial Organic Analysis, 4th edition, 1910, ii, 10.

[22] Stiepel: Zeitschrift für analytische Chemie 1911, l, 58; Seifenfabrikant xxxix, 509, 534; Pharmaceutisches Zentralhalle l, 916.

[23] Lewkowitsch: Journal of the Society of Chemical Industry 1897, xvi, 503.

[24] Lewkowitsch: Chemical Technology and Analysis of Oils, Fats, and Waxes. Fourth Edition. 1909, i, 342.

[25] Lewkowitsch: Chemical Technology and Analysis of Oils, Fats, and Waxes. Fourth Edition. 1909, i, 419.

[26] Cappenberg: Chemiker Zeitung 1909, xxxiii, 585.

[27] Bömer and Winter: Zeitschrift für Untersuchung der Nahrungs- und Genussmittel 1901, iv, 865. Bömer: Zeitschrift für Untersuchung der Nahrungs- und Genussmittel 1901, iv, 1070.

[28] U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 107 revised, 1910, 2 (paragraph $2a_4$), 3 (paragraph 2b).

[29] LeClerc and Dubois: Journal of the American Chemical Society 1904, xxvi, 1108.

[30] Dubois: Journal of the American Chemical Society 1905, xxvii, 729.

[31] U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 107 revised, 1910, 4.

[32] Gillan: Thesis. Graduate School of the University of Pennsylvania 1909. Philadelphia, Winston 1910.

[33] Wherry: JOURNAL OF THE FRANKLIN INSTITUTE 1910, clxix, 487.

[34] Hepburn: JOURNAL OF THE FRANKLIN INSTITUTE 1909, clxviii, 365, 421; 1910, clxix, 23.

[35] Bianchi: L'Orosi 1898, xxi, 253.

[36] Legler: Pharmaceutische Centralhalle für Deutschland 1904, xlv, 839.

[37] Walker: Philippine Journal of Science 1906, i, 117.

[38] Pennington and Hepburn: Journal of the American Chemical Society 1910, xxxii, 568.

[39] Pennington and Hepburn: U. S. Department of Agriculture, Bureau of Chemistry Circular No. 75, 1911; Science 1911, New Series xxxiv, 223.

[40] Kastle and Loevenhart: American Chemical Journal 1900, xxiv, 491.

[41] U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 107 revised, 1910, 117.

[42] Pennington: Journal of Biological Chemistry 1908, iv, 353.

[43] Van Slyke and Hart: New York Agricultural Experiment Station. Geneva. Bulletin No. 215, 1902, 101.

[44] Berg and Sherman: Journal of the American Chemical Society 1905, xxvii, 124.

[45] Nerking and Haensel: Biochemische Zeitschrift 1908, xiii, 348.

[46] Röhrig: Zeitschrift für Untersuchung der Nahrungs- und Genussmittel 1905, ix, 531.

[47] U. S. Department of Agriculture, Bureau of Chemistry Circular No. 66, 1911, 5.

[48] U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 107 revised, 1910, 119.

[49] Munson and Walker: Journal of the American Chemical Society 1906, xxviii, 663; 1907, xxix, 541.

NOTE.—Part I, "The Function and Equipment of the Laboratory and a Résumé of the Researches Carried Out Therein," appeared in the JOURNAL OF THE FRANKLIN INSTITUTE, June, 1911, CLXXI, 585–598. Part II, "The Scientific Study of the Handling of Perishable Foodstuffs," appeared in the JOURNAL OF THE FRANKLIN INSTITUTE, August, 1911, CLXXII, 173–193.

The Ovifaker Iron; a Natural Carbon Steel. C. BENEDICKS. (*Metallurgie,* viii, 65.)—On examining the specimens of the natural mass of iron discovered at Ovifaker by Nordenskiöld under the microscope, the results show that the mass is a natural steel containing high sulphur. The structure differs from that of meteoric iron, and shows the presence of finely divided pearlite, indicating very rapid cooling below 700° C. A new constituent was observed, which the author terms "oxide-pearlite," in which the cementite lamellæ appear to penetrate into the oxide; this oxide-pearlite was probably formed by a secondary oxidation of the ferrite lamellæ in pearlite. This confirms the view that the mass has been produced by the reduction of the iron compounds in molten basalt by a highly carbonaceous material.

Effects of Ultra-violet Radiations. A. GUNTZ and J. MINGUIN. (*Comptes Rendus,* clii, 372.)—The effects of radiations from a silica Westinghouse mercury vapor lamp, 3.5 amps., at 220 volts, are thus stated. The surface of crystals of benzylidene camphor is corroded, but the melting point and density remain constant. Sugar candy crystals are also corroded, the candy turning yellow, and a certain amount of glucose is produced. Glucose and lævulose are formed by the action of the rays on cane sugar in solution. Anthracene, in benzene solution, polymerises to *p*-anthracene; while phosphorus under water quickly becomes red (amorphous); crystalline sulphur is reduced to powder, and solutions of sulphur in carbon disulphide or benzene deposit an insoluble modification of sulphur.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, September 20, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1911.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 4.

The following amendment to the By-laws relating to the election of the Trustees, to be voted on at the next stated meeting, was presented:

Section 2 of Article 1 of the By-laws to be amended to read as follows:

SEC. 2. *Said Board of Trustees shall be composed of seven (7) members, originally elected by the Board of Managers on its own nomination.*

Vacancies, as they occur, shall be filled by election by the Board of Managers from nominations made by the remaining Trustees to a stated meeting of the Board of Managers at least one month prior to the election; the Board of Managers to have the right to reject any nominations not satisfactory to them.

The remaining members of the Board of Trustees, whenever at any time it shall be deemed necessary so to do, shall have power to assign and convey the property held by them, so as to vest the title thereto in themselves and their successors.

Dr. Hugo Lieber, president, H. Lieber & Company, New York, presented a communication on "Modern Uses and Applications of Radium." The speaker reviewed briefly the work of the various investigators in this branch of science and described some of his own researches. He referred to the application of radioactive materials in therapeutics and the action of radium on diseased tissue.

The subject was illustrated by a number of experiments and exhibits.

The thanks of the meeting were extended to Dr. Lieber for his paper. An interesting discussion followed, in which Messrs. Williams, Stratton, Snook, Gartley and Hoadley participated.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of proceedings of the Stated Meeting held Wednesday, September 6, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 6, 1911.

DR. GEO. A. HOADLEY *in the Chair.*

Two protests were considered and other business transacted.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. CONRAD LAUER, 608 Chestnut St., Philadelphia.

NON-RESIDENT.

MR. FREDERICK D. CHESTER, Chester Springs, Pa.
DR. HUGO LIEBER, 381 Fourth Ave., New York City.
DR. F. J. MACHALSKE, (temporary address) 1618 Wallace St., Philadelphia.

Changes of Address.

MR. WALTER ATLEE, 1406 G. St., N. W., Washington, D. C.
MR. RICHARD GILPIN, 505 Chestnut St., Philadelphia.
MR. J. H. GRANBERY, 145 Milton St., Brooklyn, N. Y.
MR. RUDOLPH HERING, 170 Broadway, New York City.
MR. W. G. MATTHEWS, Matthews, Florida.
MR. HENRY G. MORRIS, Commonwealth Trust Building, Philadelphia.
MR. SAMUEL F. PRICE, JR., 70 W. 46th St., New York City.
MR. JOHN RAE, 5231 Pine St., Philadelphia.
MR. T. EDWARD ROSS, 1209 Morris Bldg., Philadelphia, Pa.
MR. JOHN MORRIS WEISS, Barrett M'f'g Co., Research Dept., Shadyside, N. J.

NECROLOGY.

RESIDENT.

Mr. James C. Brooks, West Chester, Penna.
Mr. James Christie, 100 Rochelle Ave., Wissahickon, Philadelphia.
Mr. Alexander Krumbhaar, Wynnewood, Pa.
Mr. Cyrus Chambers, Jr., Overbrook, Pa.

LIBRARY NOTES.

Purchases.

LEWKOWITSCH, J.—The Laboratory Companion to Fats and Oils Industries.
WHITTAKER, E. T.—A History of the Theories of Æther and Electricity.
HILL, C. W.—Electric Crane Construction.
LAMBORN, L. L.—Modern Soaps, Candles and Glycerin.
American Electrochemical Society Transactions. Vols. 18 and 19.
International Catalogue of Scientific Literature. D. Eighth annual issue.
LEMERY, N.—Cours de chemie.
JACKSON, WM.—Dictionary of English and Spanish Technical and Commercial Terms.
SAVOIA, H.—Metallography.
BEMMELEN, J. M. VAN—Die absorption.
BÖRNSTEIN, R., and W. MEYERHOFFER.—Landolt-Börnstein physikalisch-chemische tabellen.
BRUNI, G.—Feste lösungen und isomorphismus.
WOLF-CZAPEK, K. W.—Die kinematographie.
OSTWALD, W.—Grundriss der kolloidchemie.
TOWNSEND, J. S.—The Theory of Ionization of Gases.
Verband der seifenfabrikanten. Einheitsmethoden zur intersuchung von fetten, ölen.

Gifts.

Jay Cooke, Financier of the Civil War. By Ellis Paxson Oberholtzer, Ph.D. 2 vols. Philadelphia, 1907. (From Mrs. C. D. Barney.)
General Electric Company Catalogue of Supplies, 1911. Schenectady, 1911. (From the company.)
Yerkes Observatory. Publications, vols. 1-2. Chicago, 1904. (From the Observatory.)
Illinois Bureau of Labor Statistics, 4th Report, Industrial Accidents in Illinois, 1910. Springfield, 1911. (From the Bureau.)
Institution of Civil Engineers, Minutes of Proceedings. Vol. 184, 1910-11, Part 2. London, 1911. (From the Institution.)
American Society of Mechanical Engineers, Transactions, Vol. 32, 1910. New York, 1911. (From the Society.)
Connecticut Geological and Natural History Survey, Vol. 3, 1910. Hartford, 1910. (From the Survey.)
American Society Heating and Ventilating Engineers, Transactions, Vol. 15, 1909. New York, N. D. (From the Society.)
Sydney University Engineering Society, Proceedings, Vol. 15, 1910-'11 Session. Sydney, N. D. (From the Society.)
Iron and Steel Institute Journal, 1911, Part I, Vol. 83. London, 1911. (From the Institute.)
Iron Age Directory, 1911. New York, 1911. (From the *Iron Age*.)
Philadelphia Maritime Exchange, Thirty-sixth Annual Report, 1910. Philadelphia, 1911. (From the Exchange.)
British Association for the Advancement of Science, Report of the Eightieth Meeting at Sheffield, 1910. London, 1911. (From the Association.)

Manila Bureau of Education, Bulletin No. 32. "Courses in Mechanical and Free-Hand Drawing." Manila, 1910. (From the Bureau.)

Muses de La Plata, Revista Tomo 17, Catalogo de la Seccion Anthropologica. Buenos Aires, 1911. (From the Museum.)

New York State Education Department, Annual Report, 1910. Albany, 1911. (From the State Library.)

Northampton Polytechnic Institute, Announcements 1911–'12. London, 1911. (From the Institute.)

Canada Royal Society, Proceedings and Transactions, Vol. 4, Third Series, 1910. Ottawa, 1911. (From the Society.)

Ontario Agricultural Societies, Eleventh Annual Report, 1911. Toronto, 1911. (From the Department of Agriculture.)

U. S. Department of Agriculture, Field Operations of the Bureau of Soils for 1900, 1902, 1903, 1904, with maps. Washington, D. C., 1901–1905. (From the Department.)

PUBLICATIONS RECEIVED.

A Concise History of Chemistry. By T. P. Hilditch. 263 pages, illustrations, 12mo. New York, D. Van Nostrand Co., 1911. Price, in cloth, $1.25.

Wolfram. Eine Monographie mit einem Anhang die Patentansprüche über Wolfram-Glühkörper von Dr. phil. Heinrich Leiser. 222 pages, illustrations, 8vo. Halle a. S., Wilhelm Knapp, 1910. Price, in paper, 12 marks.

Providence, R. I., City Engineer. Annual Report for the year 1910. 87 pages, illustrations, plates, 8vo. Providence, City Printers, 1911.

The Strength of Flat Plates. By Tandy A. Boyson. Rensselaer Polytechnic Institute. Engineering and Science Series No. 2. 15 pages, illustrations, 8vo. Troy, N. Y., Institute, 1911.

U. S. Department of Agriculture, Forest Service, Bulletin No. 90. Relation of Light Chipping to the Commercial Yield of Naval Stores. By Charles H. Herty, Ph.D. 36 pages, illustrations, plates, 8vo. Office of Public Roads, Bulletin No. 38. Methods for the Examination of Bituminous Road Materials. By Prévost Hubbard and Charles S. Reeve. 45 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

Ontario Bureau of Mines. Twentieth Annual Report, 1911, Part II. The Porcupine Gold Area. By A. G. Burrows. 39 pages, illustrations, plates, maps, 8vo. Toronto, King's Printer, 1911.

Report of Test of Atlas Crude-oil Engine. (Diesel type), June, 1911. By C. E. Sargent, M.E., Chicago. 4 pages, tables, plates, quarto. Indianapolis, Ind., Atlas Engine Works, 1911.

Southwark-Rateau Steam Turbines, Turbo Pumps and Blowers. 3 pamphlets, illustrations, 8vo. Philadelphia, Southwark Foundry and Machine Company, 1911.

Eighth International Congress of Applied Chemistry, Washington, 1912. Preliminary Announcement and Announcement No. 2, American Manufacturers' Pamphlet, Special Committees and Topics. 2 pamphlets, 8vo. New York, 1911.

CURRENT TOPICS

American Mining Congress. The fourteenth annual session of the Congress will be held in Chicago, October 24th to 28th inclusive. The convention promises to be the most successful in the history of the organization, and the following subjects will receive special consideration: The prevention of mining accidents. Workmen's compensation for the victims of mining accidents. The prevention of waste of the natural resources and conservation of the energy which now contribute to coal production. The general problems of the bituminous coal mining industry as intensified by the demand for better protection to miners and the conservation of fuel resources. The Alaskan question. The public land questions of the West as they affect the mining industry.

The Governors of Utah, Wyoming, Idaho and Arizona will lead the discussion of the "Public Land Questions of the West." The Hon. Martin D. Foster, chairman of the House Committee on Mines and Mining, will speak on the relation of Congress to the mining industry. President Bush, of the Missouri Pacific Railroad, will present a statement on the present conditions of the coal industry which will be of special interest to coal operators.

Among the other speakers are President Taft, Secretary Fisher and other officials of the Government.

Action of Caustic Soda on Cotton. J. Hübner. (*J. Soc. Dyers and Col.*, xxvii, 126.)—In 1846 Persoz refers to the value of strong caustic soda solution in dyeing manganese bronze on cotton, and to the shrinkage which the fibres undergo. This shows that the action of soda on cotton was known in France before or at the same time that Mercer made his discovery. Persoz says that manganese bronze was first applied to dyeing piece goods by Hartmann de Munster in 1815. The author found a reference to this in "Experimental Researches Concerning the Philosophy of Colours," by Bancroft, published in 1813.

New Methods of Obtaining Hydrogen. R. Blum. (*Metall. and Chem. Eng.*, ix, 157.)—In the Linde-Frank-Caro process the carbon dioxide of water gas is absorbed by caustic soda; the gas compressed to 60 atmospheres in a three-stage compressor, dried, and cooled by liquid air; the carbon monoxide and nitrogen condense and the hydrogen escapes. The residue of carbon monoxide is absorbed by soda-lime; and is used as fuel for a boiler or burned in a gas engine. The Carbonium Gesellschaft compress acetylene to two atmospheres and explode it by electric sparks, obtaining lampblack and hydrogen. Last year the company's works blew up. The Internationale Wasserstoff Co. fill retorts with porous iron oxide, reduce the hot oxide with water gas, and then pass steam through the retorts to obtain hydrogen, and recover the iron oxide for fresh use. The Berlin-Anhaltische Maschinenbau A. G. use two gas producers, lined with fire-brick, which are charged with coke; air is blown into the coke by a steam turbine, the blower is stopped and oil sprayed into the producer, yielding lampblack and hydrogen.

Dust Removal in Coal Mines. MAVOR and COULSON. (*Elect. Rev.,* lxviii, p. 833.)—This is a method for removing coal dust from the roadways of mines. Essentially it is an improvement on the vacuum cleaner. The basic principle of the apparatus is to create an artificial dust storm, by means of an air pressure jet, inside a conical nozzle connected to a suction pipe. It consists of four chief parts: (1) A bell-shaped mouthpiece attached by a bayonet joint to a suction hose. Inside the mouth-piece is a nozzle attached to a supply of compressed air, which causes a jet of air to impinge upon the surface to be cleaned, searching out the crevices, and thus raising the dust. (2) A means of obtaining a pressure air jet for disturbing the dust. (3) A means of obtaining air suction to withdraw the dust. (4) A filter or separator to retain the dust collected while allowing the air to escape. Tests with this apparatus are said to have been most successful.

Electrolytic Determination of Zinc in Ores. G. KEMMERER. (*Journ. of Ind. and Eng. Chem.,* ii, 9.)—Zinc can be accurately determined electrolytically when the electrolyte contains 20 to 25 gm. of sodium hydroxide per 100 to 150 c.c., using a current density of 3.1 ampères per square decimetre, a nickel gauze kathode and a rotating anode. The deposits obtained were all of a beautiful bluish-white, and in every case the ferrocyanide test failed to show any zinc in the remaining solution. 0.17 to 0.37 gm. of zinc was deposited in 10 to 20 minutes.

A Method of Calibrating Fine Capillary Tubes. T. R. MERTON. (*Phil. Mag.,* xxi, p. 386.)—The bore of a capillary tube is, as a rule, determined by optical measurement of the bore and by weighing a drop of mercury occupying a known length of the tube. These experiments were made in order to ascertain the accuracy with which a measurement of the electrical resistance of a fine glass capillary tube filled with mercury can be determined. From this a mean value for the radius of the tube is computed. Correction for the curvature of the stream-lines of current at the ends of the tube must be made. The results prove the simplicity and accuracy of the method.

A Method of Observing Stream-lines in Air. A. LAFAY. (*Comptes Rendus,* clii, 318.)—This is done by using a thin stream of acetylene issuing from a nozzle 2 to 3 mm. in diameter, which when illuminated casts upon a screen a refraction shadow of one bright line between two dark ones; thus the path of the gas is rendered visible. The acetylene should flow from the nozzle at the same velocity as that of the air current in which it is immersed. By this method variations in the speed of the air can be detected by the discontinuity of the shadow. The acetylene will have the same density as the air if it is cooled to about 30° C. below the temperature of the air, or if it is mixed with CO_2 in the proportion of $8C_2H_2$ to $3CO_2$. If the smell of acetylene is too objectionable, substitute ethylene.

Zodiacal Light. BIRKELAND. (*Comptes Rendus,* clii, 345.)—Several observers have noted that the zodiacal light sometimes presents very regular pulsations in intensity and form. The author finds that these pulsations correspond very closely with the periods found for regular magnetic waves in the polar regions; which suggests that the zodiacal light may have an electrical origin. Several experiments are described which were undertaken in the endeavor to confirm this view. From these it is inferred that there may be a ring of luminous matter extending in the plane of the sun's magnetic equator. There are references also to the *Gegenschein* and the formation of luminous clouds.

Definition of Intensity of Electric Current. A. OCCHIALINI. (*N. Cimento,* Ser. vi, 1, p. 65.)—Instead of the usual definitions based on hypothesis, this is an attempt to deduce a definition of intensity of current directly from experiment. By connecting a Wimshurst machine with a Grassi voltameter and a Leyden jar, it can be shown that the quantity of an electrolyte decomposed in a voltameter is independent of the time taken by the current to pass through it, of the dimensions and form of the voltameter, and also of the physical condition and concentration of the solution; depending only on, and being proportional to, the quantity of electricity. Hence the intensity of the current can be defined in terms of the quantity of the electrolyte decomposed.

Bright Color of Bronze and Composition Castings. ANON. (*Brass World,* vii, 8, 268.)—On the best grade of steam metal goods there is frequently found a bright, clean color, which some believe is obtained by an acid dip; but this is not the case. This color is due to plunging the casting at a low red heat into cold, clean water. This good color is only obtained under the following conditions: The bronze or composition must be of good quality, and must not contain too much lead, iron, antimony or other impurities. Copper ingot makers succeed in producing the beautiful rose-red color on the best grade of Lake copper ingots by the use of cold, clean water.

Cold Storage Equipment. ANON. (*Times Eng. Suppl.,* June 28, 1911.)—The ammonia system requires less power than the carbon dioxide system and is better adapted for cooling by direct expansion in tubes in the refrigerating chamber. In small plants the compressors are often driven by electric motors, and in large plants by suction gas plants. Atmosphere condensers, *i.e.,* tubes cooled by exposure to air and a water spray, require 50 to 70 per cent. less water than submerged condensers cooled by water alone. The power required for the compressors is about 1½ H. P. per ton of "refrigerating capacity" per day, equivalent to about 3 H. P. per ton of actual ice-making capacity. To cool the refrigerating chamber by air currents, previously cooled, electrically driven fans are used. A 5 or 6 H. P. motor is sufficient to drive the fans for an air-cooler supplying 80,000 to 100,000 cubic feet of storage space.

Amount of Radium in Some Uranium Ores. W. MARCKWALD and A. S. RUSSELL. (*Chem. News,* ciii, 277.)—The radium in a number of uranium ores was determined by dissolving in strong sulphuric acid, in which radium sulphate is soluble, and measuring the emanation evolved by means of its ionizing power. If the ratio of radium to uranium in Joachimsthal pitchblende is taken as 100, then the ratio in thorianite is 98.1, and in African pitchblende 101.5, but in autunite it varies from 20.7 to 68.0. A determination of ionium in autunite showed that the ratio of ionium to uranium is much more uniform than that of radium to uranium, and is also relatively higher. Since ionium's mean duration of life is not less than 30,000 years, this indicates that autunite must be at least 100,000 years old, and the relatively low numbers of the radium ratio cannot be explained by assigning to it a recent origin, as Soddy suggested. The facts are accounted for by supposing that on account of its spongy structure, as compared with the very dense pitchblende and thorianite, radium and lead have been partially extracted from the mineral by water, the occlusion of helium also being very slight. The results obtained with rutherfordite support this view.

Iron in Nickel. ANON. (*Brass World,* vii, 8, 294.)—The presence of iron in nickel makes it whiter. All nickel anodes and nickel deposits contain iron. This deposit, containing iron, although whiter than one free from iron, is more readily tarnished.

The Action of Salt Solutions and Sea-water on Iron. J. A. N. FRIEND and J. H. BROWN. (*Chem. Soc. Proc.,* xxvii, 156.)—Thin plates of pure iron were exposed to the corrosive action of various concentrations of common salt and of sea-water at different temperatures. Below 13° C. (55.4° F.) dilute solutions exert a more corrosive action than distilled water at the same temperature; above 13° C. they are less corrosive. At 13° C. the corrosive action is practically the same for dilute solutions of salt, for ordinary sea-water, and for distilled water. Therefore this temperature is named the "inversion temperature."

The Rôle of Slags in Smelting Processes. C. DICHMANN. (*Stahl und Eisen,* xxxi, 749.)—This considers the solubility of silica, bases, and silicates in each other. The slags of heating furnaces are said to be simple solutions of iron oxide in silicates, and therefore furnaces should be repaired with silica and not with bases. Each kind of furnace used in the steel industry is discussed, and it is shown that iron phosphide is removed by ferrous silicate, being oxidized to phosphate; hence to insure its removal the slag must contain plenty of oxygen.

Detecting Adulteration of Oils. ALEX. E. OUTERBRIDGE, JR. (*Iron Age,* lxxxviii, 2, 91.)—This is a valuable article for all users of lubricating oils, and is well worth their close attention. The gist of it may be stated as follows: De-bloomed mineral oils are free from bloom (fluorescence) in bright sunlight, or ordinary diffused daylight, or the light from an ordinary electric arc, but *they all become highly fluorescent* when exposed to the *ordinary enclosed arc;* which happens to give out rays of the exact wave length needed to enormously increase the fluorescence. The light should be so inclosed that the arc burns in a partial vacuum or at least the air is rarefied, and after burning a minute gives a faint rosy light in addition to the powerful white light. If a vessel containing any mineral oil, crude or refined, or any resin oil, be placed in the path of these rays, the most intense fluorescence appears, even in daylight; greenish in the case of mineral oil and blue in the case of resin oil; thin films glowing in the same manner. So strong is the fluorescence that 1 c.c. of crude mineral oil has been detected in 999 c.c. of non-fluorescent oil. "It is stated in some text-books that 'oleic acid' which is found in lard oil is fluorescent. On examination I find that pure, white, strained lard oil is entirely free from fluorescence under the ultra-violet ray, but all of the samples of so-called No. 1 or No. 2 lard oil (sold for use in machine shops) examined possess some fluorescence, and this may prove to be a novel means of rapidly determining the proportion of oleic acid in lard oil, though I only suggest it tentatively." To carry out this test systematically, it is desirable to put the standards in narrow, tubular, oil-test bottles, holding about 50 c.c. each; corked, labelled, and placed side by side in small wooden racks on a shelf in proximity to an inclosed arc light; beginning with a pure oil on the left hand side, then bottles with 0.1 per cent. mineral oil, 1 per cent., 2 per cent., etc., up to 10 per cent. The standard with linseed oil serves to examine cottonseed, corn, China-wood, China-bean oils, or any other non-fluorescent vegetable oil. The special standard of lard oil is necessary to test adulterated lard oils.

Materials for Balloon Envelopes and for Producing Gas-tightness. H. HOERNES. (*Gummi-Zeit.*, xxv, 1281.)—The materials used for balloon envelopes are: (1) *Pongee Silk.* Its advantages are its great tensile strength combined with lightness; its disadvantages are its high cost, its tendency to brittleness, and its electrical properties. (2) *Cottons,* such as *Percale* or *Calico.* Their advantages over silk are greater stability as regards atmospheric influences, but they are less strong and much heavier. Generally employed as a double layer of the fabric, with the threads either parallel or at an angle of 45° to one another, joined by an intermediate layer of rubber. (3) *Fine Linen.* Almost as costly as silk, but not as light, and therefore not desirable. (4) *Gold-beater's Skin* is very expensive, difficult to repair, and sensitive to atmospheric influences. Advantageous on account of low porosity and its high tensile strength per unit weight. (5) *Aluminum* is used in strips of sheet about 0.2 mm. thick, riveted or welded together. The materials for gas-tightness are: (1) *Linseed Oil Varnish.* Advantageous on account of low cost and ease of application and great efficiency. Objections are the need of constant attention during storage, risk of spontaneous inflammation if the air supply is insufficient, the slowness of the repairing process and tackiness at an elevated temperature. (2) *Rubber.* Used as a layer of vulcanized rubber between the layers of fabric. Repairs effected easily and rapidly, the fabric is always supple and there is no tackiness at high temperatures. On the other hand, it is high priced, susceptible to electric discharges, very heavy, and easily affected by the violet and ultra-violet rays. Other gas-tight materials are *Ballonin,* a solution of gutta-percha in benzol; *Konjaku,* a Japanese vegetable product, put on the market as a white powder, soluble in warm water; *Bi-chromated Gelatin;* and *Pegamoid.*

Solder for Aluminum. N. J. A. BOURGADE. (*French Patent,* 425, 912, 1910.)—The solder is composed of an alloy of 1 part tin and 2 parts zinc, to which 5 per cent. of its weight of cadmium is added. These proportions are variable. The solder can be used without a cleansing agent or solvent for oxide.

The Influence of Surface on the Rusting of Iron. K. ARNDT. (*Metallurgie,* viii, 353.)—The electrolytic theory of the rusting of iron is discussed in relation to the varieties of iron, such as cast iron and machined products. Graphitic grains form centres from which rusting starts. Fractures rust more readily than the outer surface, and it is suggested that a coating of silicates in the case of cast iron, and films of scale in rolled material, act as a protecting layer. The rough surface of a fracture distinctly accelerates rusting. Smooth surfaces are more resistant than rough ones.

Hardening Copper. (*U. S. Pat. No. 984,137.*)—R. A. Hamilton and J. Henry harden copper by treating it with a mixture of aluminum and iron pyrites. The aluminum is heated to a high temperature in a crucible and enough pyrites added to it to form a brittle compound, which is poured into moulds. From 1 to 3 oz. of this mixture, with charcoal and borax, are added to each pound of copper already melted.

Electric Smelting of Iron Ore at Trollhätten, Sweden. ANON. (*Board of Trade J.*, June 29, 1911.)—The report of the Swedish "Jernkontoret," or Iron and Steel Institute, for 1910, gives the results of the experiments made at Trollhätten in the smelting of iron ore by electricity, provided at low cost from the Government works. The plant cost £17,800. Operations began Nov. 15, 1910. The results show that the question of smelting iron ore by electricity is solved even from the economical point of view, if electricity is provided at low rates. Better results are expected if the gas can be more effectively circulated, which seems feasible with better arrangements. The experiment has paid expenses. It is considered that the smelting works cannot be a commercial success if the cost of electricity should exceed the present rate of £2 4s. 5d. ($11.00) per kilowatt per annum. In a five months' run the consumption of charcoal was 413 kilos per ton of iron, and of electricity 1 kilowatt per annum for 4 tons. The product was practically free from slag and oxide. Satisfactory results were also obtained at the works at Fagersta, Eskilstuna, Hagfors, and Munkfors.

Mineral Resources and Industry of Bolivia. ANON. (*Board of Trade J.*, July 6, 1911.)—Indications of gold are found all along the eastern slope of the Cordillera Real, and in the beds of the rivers flowing east from this range. The annual production of gold in Bolivia may be reckoned as 17,460 ounces of bullion, value at £72,000. The richest silver region lies in the west. In the north, south and east the silver lodes are found near the summits of the Andean range, running east and west. There is little silver in the north. The production of silver fell from £1,474,495 in 1895 to £54,472 in 1909. This diminished output is attributed to the fall in the price of the metal, and the increase in the value of tin, which is abundantly found close to the silver-bearing areas and in an easily worked condition. The silver mine owners have diverted their work and capital to tin production. Copper is found widely distributed over the highlands of Bolivia, and extending into Peru. The province of Pacajes contains the richest copper region, southwest of Lake Titicaca, known as Corocoro. The production has risen from 1518 metric tons in 1885 to 3084 metric tons in 1909. Tin is found principally in the higher peaks of the Cordillera Real, overlooking the basin of the Amazon. The ore averages 5 to 10 per cent. High grade stream tin is also found. In most operations the ore is merely crushed and washed, and concentrates of 55 to 65 per cent. tin are exported. Bolivia is the second tin-producing country in the world, only surpassed by the Straits Settlements. The principal beds of tungsten in Bolivia are in the province of Calugo, department of La Paz. The picked ore contains tungstic acid 75 to 76 per cent., ferric oxide 10 to 20 per cent., manganese oxide 4 to 15 per cent. Pools of petroleum oil and pitch are found in Eastern Bolivia extending over 300 miles, in a narrow belt.

Canadian Asbestos. ANON. (*Chamber of Comm. J.*, July, 1911.)—Canada produces 82 per cent. of the world's supply of asbestos. The capitalization of the asbestos quarries and factories of Canada amounts to $24,290,000. In 1880 only 380 tons were produced, in 1909 the output was 63,300 tons, and 2000 men were employed. In the Black Lake quarries, province of Quebec, there are 45,000,000 tons of asbestos rock in sight. The Russians are the only real rivals as regards extent of asbestos resources, but are handicapped by the cost of transportation, $35 to $40 per ton, from the mines to London. The asbestos slate or shingle industry is being developed in Canada, and it is predicted that in a short time 75 per cent. of all the asbestos produced in Canada will be used for this purpose. This asbestos slate business is only five years old, yet the demand has increased enormously, and large factories are established to supply this new roofing material.

Simultaneous Manufacture of Silicon and Pure Alumina. F. LAUR. (*French Patent*, 425, 277, March 31, 1910.)—To produce pure alumina for the manufacture of aluminum, it has hitherto been necessary to use bauxite containing a very little silica. To produce pure alumina from very siliceous bauxites, or from natural silicates, the white bauxite or kaolin may be crushed and mixed with coke, using only just enough carbon to reduce the silica (0.4 part carbon for 1 part silica). The mixture is smelted in the electric furnace, when the silicon is separated and a slag of nearly pure alumina obtained. To free the alumina from the last traces of silica, a little powdered aluminum carbide (1 per cent. for each 1 per cent. of silica) is then added whilst the liquid is stirred. This liberates the last of the silicon and separates it from the alumina, which can be removed and pulverized.

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THE MEASUREMENT OF GASES.

BY

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THE measurement of gases forms a necessary part of many scientific and commercial operations. Perhaps the most common case has to do with the rate of flow in a pipe. It is generally required to ascertain the number of "standard cubic feet" passing in a given time; this meaning the amount of "stuff" or the weight of gas passing per unit of time. The contents of a standard cubic foot are determined by the assumed standards of temperature and pressure used in defining the unit of measurement. Scientific data on gases are usually referred to the freezing temperature of water and to the mean barometric pressure. Common commercial standards of temperature and pressure in gas measurement are 60 degrees F. and 30 inches of mercury, respectively.

The object of this paper is to describe experiments with several forms of gas meters and to show how the results have been used in connection with the development of an entirely new form of meter. Aside from the use of the results in connection with the development work, they are of considerable interest from a scientific standpoint, because they are all based upon accepted scientific principles and their agreement forms an interesting

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confirmation of several theories. The experiments show that, given proper conditions, very satisfactory results can be obtained in measuring gas with any of the types of meter used during the development work, and with the new type of meter it has been possible to arrive at a very interesting check upon the accuracy of the older types. The comparative advantages and disadvantages in the operation of each type depend upon the particular conditions under which measurement is made.

The practical result which has been attained in the investigation forming the basis of this paper is the development of a meter with which continuous measurement can be carried on automatically under commercial conditions with the same degree of accuracy as is obtainable with the other types of meters by laboratory methods requiring the greatest refinement in instruments and in observations.

THE FLOW OF GASES THROUGH PIPE LINES.

When gas making was first undertaken on a commercial scale it became necessary to determine the conditions governing the rate of flow in pipes. A number of principles were enunciated by Dr. Pole and published about 1851, together with what is known as Pole's formula. An excellent discussion of Dr. Pole's work is found in a book by Mr. Walter Hole on the "Distribution of Gas," published by John Allan & Company, London. The following statement of Dr. Pole's principles and of the accompanying formulæ for flow in pipes is taken from Mr. Hole's book:

"Dr. Pole's principles:

"1. That the friction of a fluid passing through a pipe is independent of the hydrostatic pressure to which the fluid is subjected—in other words, the friction of a column of water is no greater at 100 pounds pressure than at a pressure of 1 pound, other things being equal.

"2. That the friction is strictly proportional to the area of the rubbing surface. That is to say, if the length of a pipe is doubled the friction will be doubled also. If, therefore, $l =$ length of pipe, $c =$ internal circumference, and $F =$ friction, F is proportional to lc.

"3. That the friction varies with the velocity, but the ratio is not very well determined. Approximately it varies as the square of the mean velocity. The particles of gas or water at the centre of a pipe move faster than those at the circumference, owing to the retarding action of friction. The mean velocity, therefore, is such that, being multiplied into the area of the pipe, it gives the quantity passing through. If the velocity is doubled, then friction is increased fourfold, or F is proportional to V^2.

"4. That friction is proportional to the specific gravity of the fluid, or will vary as S. Friction also is absolutely independent of the position of the pipe, other things being equal. It makes no difference whatever to friction whether the pipes are made to assume a horizontal, vertical, or inclined position. It is the same in each case."

Following out the reasoning briefly given above, Dr. Pole ultimately arrives at a working formula, which is as follows:

$$V = 1350 d^2 \sqrt{\frac{p\,d}{s\,l}}$$

where

$v =$ volume of gas discharged in cubic feet per hour.
$d =$ diameter of pipe in inches.
$p =$ pressure in inches of water above atmosphere.
$s =$ specific gravity of gas (air $= 1$).
$l =$ length of main in yards,
and 1350 is a constant deduced from practical experiment.

According to Professor Unwin, the coefficient of friction varies from .0082 for a 2-inch main to .0063 for 4-inch, .0053 for 8-inch and .0048 for 18-inch. Dr. Pole assumed a uniform value of .0060.

The following laws are derived from the formula:

(1) By increasing the pressure fourfold the discharge is doubled.

(2) By increasing the length fourfold the discharge is halved.

(3) By increasing the length fourfold, four times the pressure will be necessary if the discharge is to remain the same. And as a further deduction from this,

(4) The pressure necessary to the discharge of a stated quantity of gas through a pipe of given diameter varies directly as the length of the pipe.

(5) By decreasing the length to one-fourth the discharge is doubled.

(6) By increasing the diameter four times the discharge is increased thirty-two times.

(7) In this equation the pressure is understood to be that necessary to force the gas through the pipe and the latter is assumed to discharge into the air at atmospheric pressure. If the discharge is to take place at a given pressure above atmosphere, then that pressure must be added to the pressure necessary to the discharge and applied at the inlet of the pipe.

Various modifications are necessary to allow for pipes other than straight and level, for bends, varying back pressure, etc.

The following modification of this formula by Professor Unwin takes account of sloping mains:

$$Q = \frac{\pi}{4} d^2 v$$

$$v = 4.012 \sqrt{\frac{d\,h}{F\,l}}$$

$$h = 780 \frac{y_1 - y_2}{s} + \left(z_1 - z_2\right)\left(1 - \frac{1}{s}\right)$$

where

Q = discharge in cubic feet per second.
d = diameter of pipe in feet.
v = velocity in feet per second.
h = head in feet of gas.
y_1 = initial pressure in feet of water.
y_2 = outlet pressure in feet of water.
z_1 = initial position with respect to horizontal datum line.
z_2 = final position with respect to horizontal datum line.
F = coefficient of friction.
s = specific gravity of gas.
l = length of pipe in feet.

Although these formulæ give fairly reliable results when applied to the discharge of gases of low pressures, they do not take into account the varying densities and volumes when the gases are subjected to higher pressures, such as those encountered in natural gas work. Taking into account these changes in volume and density, Professor Unwin arrived at the following equations:

$$Q = \frac{\pi}{4} d^2 u_2 = \frac{\pi}{4} \frac{p_1}{p_2} d^2 u_1$$

where

Q = discharge in cubic feet per second measured at the pressure p_2.
d = diameter of the pipe in feet.
u_1 = the velocity in feet per second at the inlet of the pipe.
u_2 = the velocity in feet per second at the outlet of the pipe.
p_1 = the absolute pressure at the inlet of the pipe.
p_2 = the absolute pressure at the outlet of the pipe.

The value of u_1 may be obtained from the following formula:

$$u_1 = 468 \sqrt{\frac{d}{Fsl} \; \frac{p_1^2 - p_2^2}{p_1^2}}$$

where

d = diameter of the pipe in feet.
l = length of pipe in feet.
s = specific gravity of the gas.
F = coefficient of friction.
p_1 = absolute pressure at the inlet of the pipe.
p_2 = absolute pressure at the outlet of the pipe,

and $u_2 = \frac{p_1}{p_2} u_1$

The demand for a reliable and convenient formula for use in natural gas work in America has brought forth the following representative formulæ:

Professor Lowe's Formula:

$$Q = C \sqrt{\frac{d^5 (p_1 - p_2)(p_1 + 14.7)}{0.0761 \times s \times l \times 14.7}}$$

where

Q = discharge of gas in cubic feet per minute at atmospheric pressure.
C = a constant depending on the size of the pipe, varying from 52.7 for a 2-inch pipe to 63.2 for a 24-inch.
p_1 = initial gauge pressure in pounds.
p_2 = final gauge pressure in pounds.
d = diameter of pipe in inches.
l = length of pipe in feet.
0.0761 = weight of one cubic foot of air at atmospheric pressure.
s = specific gravity of the gas.

Oliphant's Formula:

$$Q = 42\,a \sqrt{\frac{p_1^2 - p_2^2}{l}}$$

where

Q = quantity discharged in cubic feet per hour.
p_1 = absolute pressure in pounds per square inch at the inlet.
p_2 = absolute pressure in pounds per square inch at the outlet.
l = length of main in miles.
a is a multiplier, varying from 16.5 for a 3-inch pipe to 2055.0 for a 20-inch pipe.

The Pittsburg Formula:

$$Q = 3450\sqrt{\frac{d^5(p_1^2 - p_2^2)}{l}} \quad \text{when } s = 0.60,$$

and Coxe's Formula:

$$Q = 41.3\sqrt{\frac{d^5(p_1^2 - p_2^2)}{L}} \quad \text{when } s = 0.65.$$

In these formulæ,

Q = discharge in cubic feet per hour.
p_1 and p_2 = absolute initial and terminal pressure, respectively, in pounds per square inch.
d = internal diameter of pipe in inches.
L = length of main in miles.
l = length of main in feet.
s = specific gravity (air = 1).

The following table shows a comparison of results computed from these various formulæ with measured results. The measured results given were obtained by Mr. George Helps, of Nuneaton, and are for discharge through a 3-inch main three miles long from the three different inlet pressures to atmospheric pressure at the outlet:

	Discharge in Cubic Feet per Hour.		
	5 lbs. Gauge Pressure	10 lbs. Gauge Pressure	18 lbs. Gauge Pressure
Discharge by measurement,	5,000	10,000	18,000
By Formulæ:			
Professor Unwin,	4,852	7,429	11,268
Professor Lowe,	5,520	8,700	13,500
Pittsburg,	6,226	9,629	14,136
Oliphant,	5,287	8,011	11,773
Coxe	5,541	8,360	12,318

From a comparison of the results obtained with the different formulæ it is seen that they can be used for rough approximations only. It is quite probable that the measured results given are in error, but it is very difficult to obtain results to check these formulæ on account of the irregular shapes of pipe lines, the presence of fittings, and the difficulty of obtaining steady flow throughout a long pipe for a sufficient time. For the same reason it would be difficult to make use of the formulæ for the practical measurement of flow through pipe lines, even if they were correct for steady flow through straight pipes.

Mr. Forrest M. Towl has made some very thorough and interesting investigations of the pressure drops in a long natural gas line from which he has derived reliable coefficients for a formula similar to the "Pittsburg" formula. In these tests the rate of flow was carefully measured as well as the pressures at various points in the line, and great pains were taken to obtain steady flow throughout the pipe.

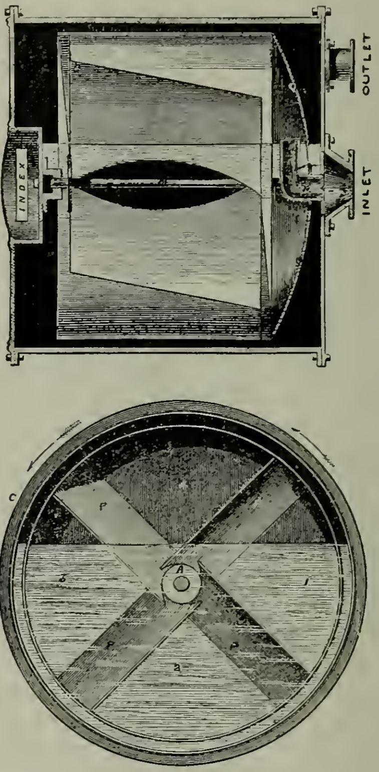
It is evident that it would be very unsatisfactory to use gas transmission lines as meters for measuring the flow of gas through them by observing the physical properties of the entering and exit gas, and it would be impossible to make use of such lines for reliable commercial measurement unless each line was very thoroughly calibrated after being installed and the flow of gas was kept steady. Some form of meter must be inserted in the line, and from the above consideration it would seem necessary, if accurate results are to be obtained, that the meter be comparatively short, so that the portion of the gas passage between the sections at which physical observations are made may have no effect upon the flow other than that intended.

METERS.

A quite general classification of meters includes two main types: volumetric meters and velocity meters.

Volumetric meters include what are known as dry meters, operating on the general principle of a bellows, and "wet meters." The latter are built in large sizes for use at gas works in measuring the gas as made, before being passed for storage to the holders. These meters are known as station meters. Their construction is, in general, that of a drum revolving within a large cylindrical tank which is approximately two-thirds filled with water. The revolving drum consists of a shaft carrying three or four partitions arranged in a spiral form. These partitions emerge in turn from the water as the shaft revolves, and each forms with the water a water-sealed compartment, which alternately receives and delivers gas. The drum receives its motion from the pressure of the gas itself as exerted upon its surfaces. The general construction of a wet meter is illustrated in Fig. 1.

FIG. 1



Longitudinal and transverse sectional views of wet displacement meter.

Gas holders have at times been used for measuring gas, but temperatures in a large holder vary so widely, due to the heat of the sun and other causes, that holder tests are in general quite unreliable. However, small holders, having a capacity of 5 to 10 cubic feet, can be very satisfactorily used for checking the accuracy of other volumetric meters. These small holders are known as meter provers.

A well-known form of the velocity type is the Rotary Meter, which works upon the anemometer principle, the amount of gas passing per unit of time being taken as proportional to the speed at which the vanes revolve.

These meters are all more or less satisfactory for commercial measurement under certain limited conditions. This paper, however, deals with meters of three types differing from the above, and based upon fundamental principles; and aims to show the comparative value of the results that can be obtained with them under similar conditions of refinement in methods of operation. It also aims to describe the methods of obtaining these results.

The three types of meter referred to in the following are: the Pitot tube, which depends for its operation upon fundamental principles of hydraulics; the Venturi meter, which depends upon thermodynamic principles involving the ratio of specific heats at constant pressure and constant volume, the ratio of cross sectional areas of throat and pipe, and the ratio of pressures in throat and pipe respectively; and the heat or electric meter, based upon a very simple principle of thermodynamics involving the specific heat of the gas at constant pressure,—in which the temperature of the gas is increased through a known range by a measurable amount of heat.

THE PITOT TUBE.

The Pitot tube affords a means of measuring the velocity of air or gas through a pipe at any given point in the pipe section. In its simplest form it consists of two small tubes inserted in the pipe line, one having an opening pointed up stream and communicating to one end of a U-tube the pressure due to velocity head in addition to the static pressure in the pipe; the other having an opening at right angles to the direction of flow and communicating to the opposite side of the U-tube the static pressure only. The difference between these two pressures is the pressure due to velocity alone, and from this the velocity of the gas in the pipe can be computed by means of the formula, $v^2=2gh$ where h is the static head necessary to give to the air or gas a velocity of v feet per second. From a knowledge of the cross sectional area of the pipe and the density of gas at the observed pressure and temperature, the quantity passing per unit of time can be computed.

The velocity of the gas flowing through a pipe is not the same at all points in the section. It falls off gradually from the centre outward and very rapidly near the inner skin of the pipe. In order to obtain accurate results with Pitot tubes without exploring the pipe at several different depths, and averaging the readings by the zone method, it is necessary to "standardize" the tube and the pipe together and find the depth at which the tube will indicate the mean velocity; that is, a Pitot tube will not necessarily give consistent readings if placed in a given position in pipes of different sizes, different conditions of surface, etc. The tube must be located with special reference to the size, shape, and condition of the pipe with which it is to be used. Great care must be taken that the openings through which the pressures are communicated to the U-tube are properly placed with respect to the direction of flow, and they must be kept free from deposits.

THE VENTURI METER.

The Venturi meter consists of a throat or gradually contracted portion of the passage which causes a decrease in pressure and an increase in velocity of the gas flowing through it.

Let A_1 = area of the upstream section.
A_2 = area of throat.
P_1 = pressure at upstream side.
P_2 = pressure at throat.
G_1 = weight of gas at upstream section.
n = ratio of specific heats at constant pressure and constant volume respectively.
V_2 = velocity of gas at the throat.

By equating the loss in potential energy to the increase in kinetic energy, it is found that

$$V_2 = \left(\frac{P_1}{G_1}\right)^{\frac{1}{2}} \left(\frac{2gn}{n-1}\right)^{\frac{1}{2}} \left\{ \frac{1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}} \right\}^{\frac{1}{2}}$$

and if Q is the quantity flowing,

$$Q = A_2 V_2 G_1 \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

The observations necessary to obtain results with the Venturi meter are the pressure of the gas or air at the upstream side, the difference in pressure between the upstream side and the throat, and the temperature at the upstream side.

As will be seen from the readings taken on the test herein described, it is very often necessary, with both the Venturi meter and the Pitot tube, to read very small differences of pressure. In order to determine these accurately it is necessary to read the water columns with either a micrometer gauge or with a differential (inclined) water column. Pulsations in the gas main interfere with taking accurate readings even with the precision instruments used in these tests, but such precaution as it was possible to use has given results that mutually agree within a small percentage. Deposits on the throat of the Venturi meter must be avoided and for both the Pitot tube and Venturi meter a considerable length of approach should be provided in order to insure a steady flow, free from eddies and pulsations.

THE ELECTRIC METER.

The "heat," or "electric" meter is based upon the principle of heating the air or gas through a known range of temperature and measuring the energy required to cause the change in temperature. This measured energy is proportional to the weight of gas flowing. Electric energy is used as a source of heat because it can be so conveniently and accurately applied and measured. Electrical resistance thermometers are used to regulate the temperature range through which the gas is heated, because with thermometers of such type very small differences of temperature can be accurately and easily determined.

If E is the amount of energy required to raise the temperature of Q units of weight of gas or air through t degrees, and if s is the specific heat of the unit of weight at constant pressure, then

$$Q = \frac{E}{t \times s}$$

In this type of meter the heater unit has its resistance material evenly distributed over the section of the passage so that all of the gas is heated. The resistance thermometer screens are likewise evenly distributed over the passage so that the temperatures of the gas are accurately integrated. This meter is therefore independent of the variation in velocity of the gas at different parts of the pipe and the gas does not need to approach it through long lengths of straight pipe. Rapid fluctuations in flow do not interfere with its accuracy on account of the slight heat "capacity" of the thermometers, which causes a time lag of a few seconds in the operation of the controlling mechanism. Since the measurements involved in this meter are all those of electrical quantities, the observations can be made very conveniently with the greatest degree of refinement, and at any reasonable distance from the meter itself. Deposits on the inner passages of the meter or upon the heater or thermometer units have no effect upon the accuracy of the meter and can only cause the units to be somewhat slower in their action than when perfectly clean.

Since all three of these methods of measurement are based directly upon fundamentally correct theories, they should all agree as to results when properly applied, in a given pipe, to the measurement of a given flow of gas or air. One of the purposes of this paper is to show how this has been proven by tests made in the Engineering Laboratory of the University of Wisconsin and also by very complete comparative tests of commercial types of the meters under conditions of regular operation.

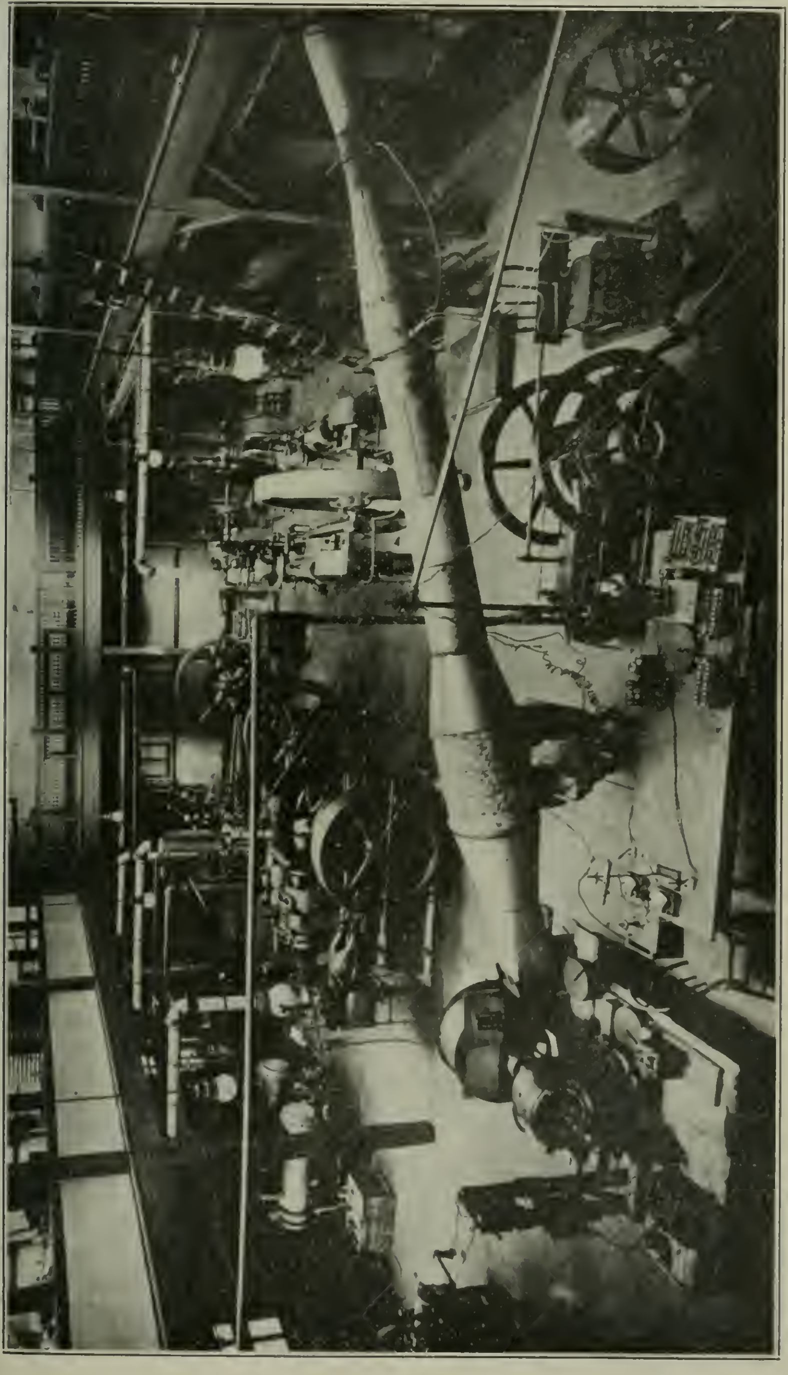
COMPARATIVE LABORATORY TESTS.

The three meters in laboratory form were arranged in series in a pipe line through which air was passed by means of a fan, as shown in Figs. 2 and 3. The fan was driven by a motor and the rate of flow of air was regulated by the speed of the fan.

Fig. 4 shows a detail of the Pitot tube. The opening at *A* points upstream and communicates through the tube *A* the pressure and velocity head, while small holes or slots (both in these experiments), opening at right angles to the direction of flow, communicate the pressure head through tube *B*. The difference in these two heads was observed in inches of water on an Ellison inclined pressure gauge graduated to hundredths of an inch. The readings were estimated to thousandths of an inch.

The shank *C* of which the pressure tubes formed a part passed through a bushing attached to the outside of the pipe, making it possible to slide the tube to any point between the centre of the pipe and its inside surface. The position of the Pitot tube with respect to the centre of the pipe could be read from a scale on the shank. The velocity head was determined at one-

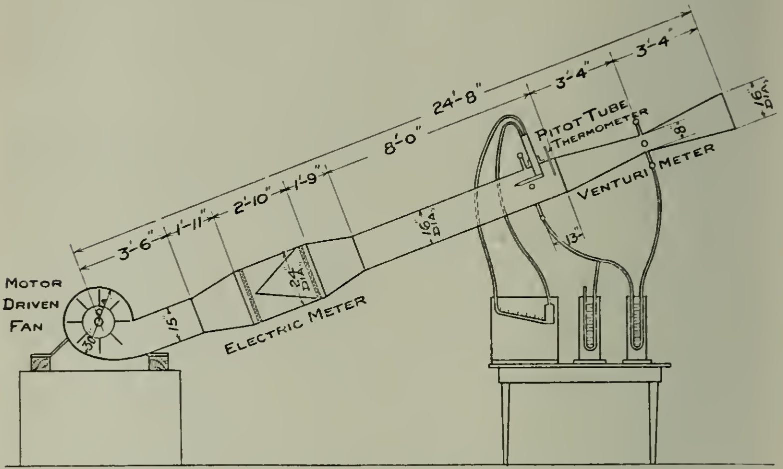
FIG. 2.



Apparatus for air tests; Gas Engineering Laboratory, University of Wisconsin.

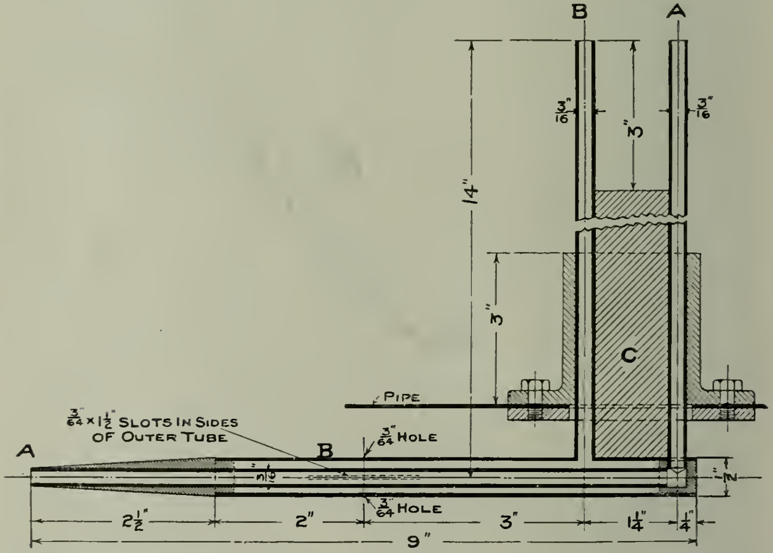
inch intervals from the centre of the pipe to five inches out and at one-half inch intervals from this point to within one-half inch

FIG. 3.



Diagrammatic sketch of apparatus showing general dimensions.

FIG. 4.

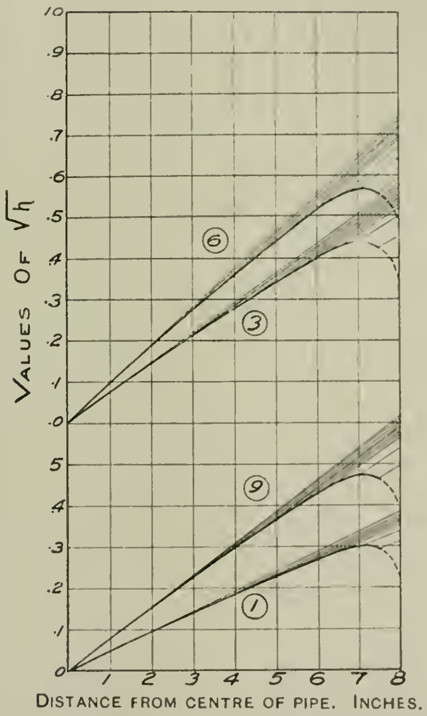


PITOT TUBE.

of the inner surface. From these readings the mean value of *h* was determined as follows:

Let a horizontal line, Figs. 5 and 6, represent the radius of the pipe. On this line lay off points to a suitable scale representing the distances from the centre of the pipe at which readings of h were observed, and erect perpendiculars at these points. On the perpendicular representing the inner surface of the pipe lay off to some suitable scale values of $\sqrt{h}$. Join the points representing values of $\sqrt{h}$ to the point on the horizontal line representing the centre of the pipe. The intersections of the resulting slanting lines from each of the points representing $\sqrt{h}$ with the perpendiculars representing the positions at which the corresponding values of $\sqrt{h}$ were read are points through which a smooth curve can be traced. The area under the curve may now be determined, and from this may be found the altitude of a triangle having the same area and the same base as the irregular figure. This altitude reduced to the proper scale will give the

FIG. 5.

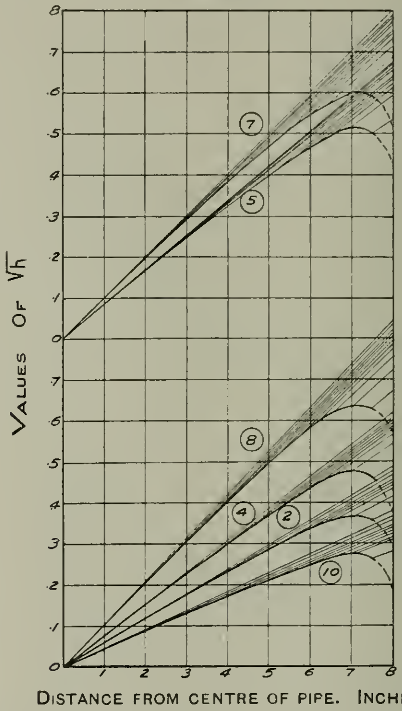


Graphical method of determining mean velocity head for Pitot tube.

mean value of $\sqrt{h}$ from which the mean value of velocity may be computed. This method was devised by Professor G. H. Davis, of the University of Wisconsin.

It was found by experiments made with this particular Pitot tube and pipe that the mean value of h occurs at 0.83 of the distance from the centre of the pipe to the side. The mean line and the curves representing variation of velocity from the centre of the pipe to the side are shown in Fig. 7.

FIG. 6.



Graphical method of determining mean velocity head for Pitot tube.

The mean velocity in the pipe is calculated from the formula,—$V^2 = 2gh$. This mean velocity is in feet per second, h having been reduced to its equivalent in feet of air.

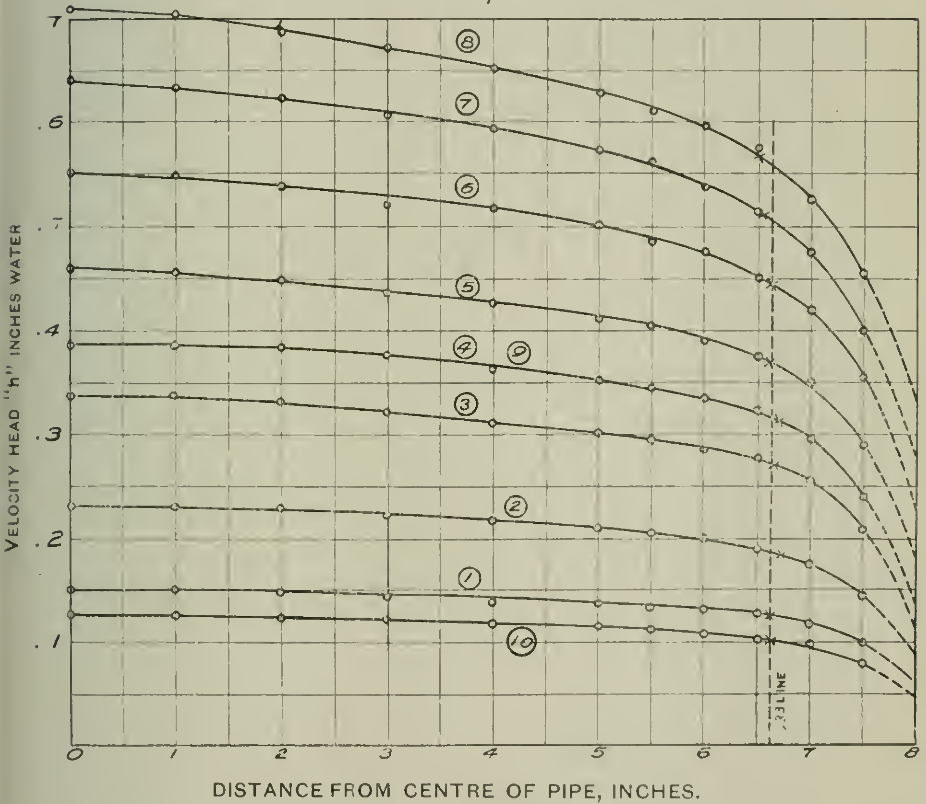
The pounds of air per hour then equal 3600 AVG, where

A = area of pipe in square feet,
V = velocity in feet per second,
G = weight of a cubic foot of the air as it passed through the pipe.

THE VENTURI METER.

The arrangement of the Venturi meter used in the tests is shown in Fig. 3. The pressure of the air on the upstream side was measured by means of a water column read by a micrometer scale to 1/500 of an inch. The difference in pressure between throat and upstream side was measured on a differential water gauge graduated in tenths of inches which could be read accurately to hundredths of an inch. From the barometer reading and from the above two readings the absolute pressures at both upstream side and throat were found.

FIG. 7.



PITOT TUBE.—VELOCITY HEAD "H" VS. DISTANCE FROM CENTRE OF PIPE.
Mean velocity head —.83 distance from centre of pipe.
X location on curve of calculated mean velocity head.

The values of the following terms,—

$$\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}},\quad \left(\frac{P_2}{P_1}\right)^{\frac{2}{n}},\quad \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

which appear in the formula for velocity were determined from a set of carefully prepared curves giving values of these expressions for different values of the ratio of pressures, n representing the ratio of specific heats at constant pressure and constant volume respectively, and taken as 1.406.

The temperature of the air at the upstream pressure P_1 was read on a standard calibrated thermometer, and the readings reduced to absolute temperature in degrees F. The humidity of the air was determined by means of wet and dry bulb thermometers placed near the suction to the fan. The per cent. humidity was taken from tables by applying the observed temperature readings. From the steam tables of Messrs. Marks and Davis the vapor pressures at the various temperatures were noted. The product of vapor pressure and per cent. humidity gives the pressure in the air due to moisture, and the pressure due to dry air alone is found by deducting the vapor pressure from the total pressure P_1. The weight per cubic foot of dry air under the conditions noted was added to the computed weight of moisture present, the result giving the weight per cubic foot of air as it passed the Venturi meter.

The upstream section of the pipe was 16 inches in diameter and the throat section was 8 inches. The square of the ratio of throat to upstream area $\left(\frac{A_2}{A_1}\right)^2$ was found to equal 0.06262 after allowance was made for the presence of the Pitot tube in the pipe.

THE ELECTRIC METER.

The electric meter used in the test is shown diagrammatically in Fig. 8. Within the pipe is an electric heater unit between two electric thermometer units T_1 and T_2. The heater consists of spiral turns of bare resistance wire wound around a conical supporting frame so that heat is dissipated evenly over the section of the pipe. In the heater circuit is a rheostat for regulating the electrical energy supplied to the heater and instruments for measuring this energy.

The thermometer units consist of resistance wire evenly distributed over the section of the pipe, and of such material that their resistance increases when their temperature is increased. They form two arms of a Wheatstone bridge, the other two arms being fixed coils of wire that have a zero temperature coefficient. Across the Wheatstone bridge is a galvanometer, and in series with one thermometer is a small rheostat for balancing the bridge. In series with the entrance thermometer is also a small resistance R_T, equal in value to the increase in resistance in the exit thermometer for a rise in temperature of about 2 degrees F. (in this particular case 2.024 degrees).

FIG. 8.

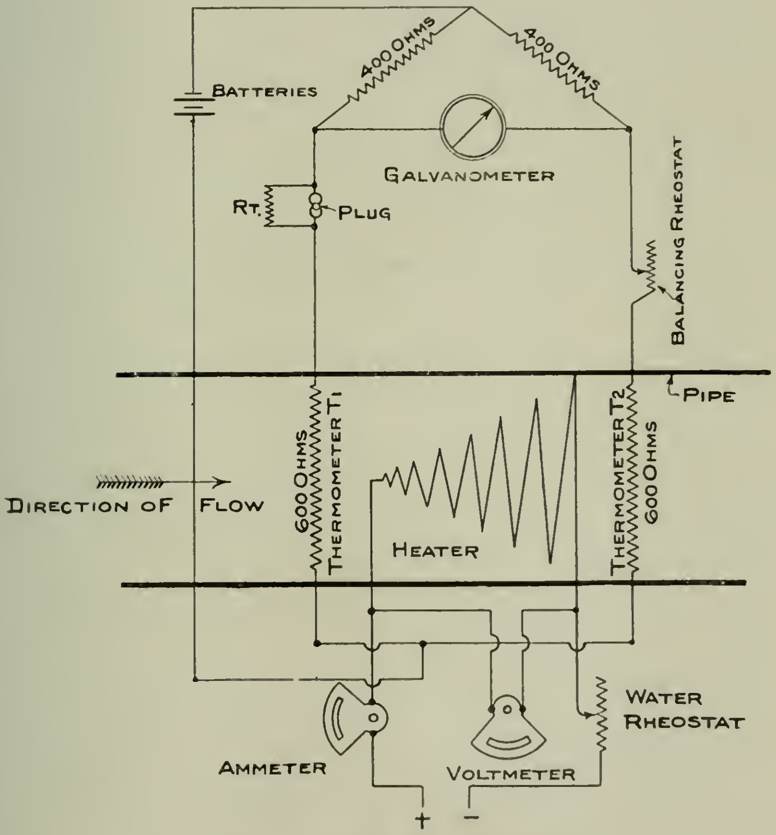


DIAGRAM OF ELECTRIC METER CONNECTIONS.

This temperature difference resistance is arranged so that it can be conveniently shorted out. The operation of this meter is as follows:

NO., OF TEST			1	2	3	4	5	6	7	8		9	10	
PITOT TUBE READINGS	DISTANCE FROM CENTER OF PIPE	.0	.150	.230	.336	.385	.460	.552	.640	.710		.385	.125	
		1.0	.150	.230	.336	.385	.455	.548	.632	.705		.385	.125	
		2.0	.148	.228	.330	.383	.448	.538	.622	.685		.378	.123	
		3.0	.143	.222	.320	.370	.435	.520	.605	.670		.365	.120	
		4.0	.138	.216	.310	.362	.425	.516	.592	.650		.357	.117	
		5.0	.136	.210	.300	.352	.410	.500	.572	.627		.348	.114	
		5.5	.133	.205	.294	.345	.405	.485	.562	.610		.340	.112	
		6.0	.131	.200	.285	.335	.390	.475	.538	.595		.332	.109	
		6.5	.128	.190	.277	.322	.375	.450	.515	.575		.320	.102	
		7.0	.117	.175	.255	.295	.350	.420	.475	.525		.292	.099	
		7.5	.100	.145	.208	.240	.290	.355	.400	.455		.248	.080	
VENTURI	METER													
		(″H_2O)												
		DIFF. IN PRESS	1.57	2.60	4.15	4.56	5.40	6.74	7.90	8.80		4.60	1.36	
		PRESS	.43	.655	.93	1.085	1.20	1.52	1.765	2.07		1.15	.46	
		TEMP.	82	83	84	85	85	87	89.5	91		90	85	
FAN		R.P.M.	450	565	680	740	800	897	956	1025		740	408	
HYDRO-	METER													
		WET	73.5	73.0	74.0	74.0	74.0	74.5	76.5	77.5		78.0	75.5	
		DRY	82.0	83.0	83.5	84.0	84.0	84.5	86.5	88.0		88.0	855	
		TEMP.	79	80	81	81	81	82.5	86	87.5		87	83	
ELECTRIC	METER													
		VOLTS	55.5	62.4	68.5	71.5	74.0	78.5	80.5	84.0		71.4	52.4	
		AMPS	22.0	24.7	27.2	28.5	29.5	31.2	32.0	33.3		28.3	21.0	
		BAROMETER	29.044	29.044	29.044	29.044	29.044	29.034	29.034	29.034		29.034	29.034	
		TEMP.	79	79	79	79	79	79	79	79		79	79	

GENERAL LOG OF AIR TESTS.

University of Wisconsin, Gas Laboratory, June 2, 1911.

With air or gas flowing through the meter but with no energy in the heater, and with the temperature-difference resistance R_T shorted out, the two thermometers are brought to exact balance by means of the balancing rheostat and the galvanometer. Then the resistance R_T is cut in and sufficient electrical energy is supplied to the heater to bring the galvanometer to a balance again; that is, sufficient electrical energy is supplied to bring the

VENTURI METER

NO., OF TEST	1	2	3	4	5	6	7	8		9	10
BAROM., (LBS/□")	14.2315	14.2315	14.2315	14.2315	14.2315	14.2315	14.2266	14.2266		14.2266	14.2266
P_1 (" H_2O)	.430	.655	.930	1.085	1.200	1.520	1.765	2.070		1.150	.460
P_2 (MINUS) (" H_2O)	1.140	1.945	3.220	3.485	4.200	5.220	6.135	6.730		3.450	.900
P_1 (LBS/□")	.0155	.0237	.0336	.0392	.0433	.0548	.0637	.0747		.0415	.0166
P_2 (MINUS) (LBS/□")	.0412	.0702	.1160	.1258	.1515	.1882	.2215	.2430		.1245	.0325
P_1 (ABS.)	14.2470	14.2552	14.2651	14.2707	14.2748	14.2863	14.2903	14.3013		14.2681	14.2332
P_2 (ABS.)	14.1903	14.1613	14.1155	14.1057	14.0800	14.0433	14.0051	13.9836		14.1021	14.1941
P_2/P_1	.996	.994	.991	.989	.987	.983	.981	.978		.988	.997
Humidity 63%											
TEMP., AIR °F	82	83	84	85	85	87	89.5	91		90	85
WT., CU. FT., DRY AIR	.07327	.07314	.07300	.07287	.07287	.07261	.07220	.07207		.07221	.07287
WT., CU. FT., VAPOR	.00167	.00172	.00178	.00183	.00183	.00195	.00210	.00220		.00213	.00183
G_1 (LBS/CU. FT.)	.07432	.07422	.07412	.07402	.07402	.07384	.07352	.07345		.07355	.07402
A_2 (□ FT.)	.349	—	—	—	—	—	—	—		—	—
$\sqrt{\frac{2gn}{n-1}}$	14.898	—	—	—	—	—	—	—		—	—
$(P_2/P_1)^{\frac{1}{n}}$	.9971	.9956	.9935	.9920	.9906	.9878	.9863	.9842		9912	9978
$(P_2/P_1)^{\frac{2}{n}}$	.9940	.9912	.9870	.9840	.9812	9755	.9724	.9682		.9825	.9955
$(P_2/P_1)^{\frac{n-1}{n}}$	.9988	.9982	.9973	.9967	9961	.9949	.9944	.9934		.9964	.9991
$(A_2/A_1)^2$	.06262	—	—	—	—	—	—	—	—	—	—
$\sqrt{P_1 \text{ times } 144 / G_1}$	166.0	166.4	166.6	166.9	167.0	167.1	167.3	167.5		167.2	166.5
$\sqrt{\frac{1-\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{1-\left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}}}$	.0358	.0438	.0537	.0593	.0645	.07375	.0773	.0839		.0619	.0310
Q (LBS PER HR)	8250	10400	12320	13600	14780	16870	17560	19000		14110	7130

$$Q\text{ (lbs. per hr.)} = 3600\, A_2 G_1 \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} \sqrt{\frac{2gn}{n-1}}\, \sqrt{\frac{P_1}{G_1}}\, \sqrt{\frac{1-\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{1-\left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}}}$$

CALCULATIONS FOR AIR TESTS.

University of Wisconsin, Gas Laboratory, June 2, 1911.

exit air or gas to a temperature two degrees higher than that of the entering gas, regardless of the absolute temperature of the entering gas. The measuring instruments in the heater circuit then indicate the energy required to raise the temperature of the air or gas through a known range.

Electric Meter

No., of Test	1	2	3	4	5	6	7	8		9	10
Wt. Dry Air Per Cu Ft.	.07327	.07314	.07300	.07287	.07287	.07261	.07220	.07207		.07221	.07287
Wt. Water Vapor Per Cu Ft. of Air 63% Saturation	.00105	.00108	.00112	.00115	.00115	.00123	.00132	.00138		.00134	.00115
Sp., Ht., Dry Air Lb.	0.2375										
Sp. Ht. Vapor Lb.,	0.48										
Sp. Ht. per Lb of Air 63% Sat.	.2410	.2410	.2410	.2415	.2415	.2415	.2419	.2420		.2418	.2415
Volts	55.5	62.4	68.5	71.5	74.0	78.5	80.5	84.0		71.4	52.4
Amperes	22.0	24.7	27.2	28.5	29.5	31.2	32.0	33.3		28.3	21.0
Watts	1222	1541	1812	2039	2183	2448	2575	2797		2021	1100
Lbs., Air per Hr. $= \frac{\text{Watts} \cdot 3.412}{\text{Spec., Ht.} \cdot 2.0239}$	8550	10790	12670	14220	15230	17100	17950	19480		14100	7580

Pitot Tube

No., of Test	1	2	3	4	5	6	7	8		9	10
Mean h (″H_2O)	.125	.187	.272	.315	.368	.444	.505	.558		.318	.100
Mean h (Ft. Air)	8.75	13.10	19.10	21.42	25.85	31.25	35.70	39.58		21.42	7.03
Mean Vel., (Ft. per Sec.) $= \sqrt{2gh}$	23.70	29.00	35.00	37.18	40.75	44.80	47.90	50.45		37.18	21.25
Wt. Cu Ft. = G	.07432	.07422	.07412	.07402	.07402	.07384	.07352	.07345		.07355	.07402
Lbs. Air per Hr. $= 3600\sqrt{2gh}\ AG$	8860	10310	13020	13820	15170	16650	17720	18610		13750	7900
A = Area = 1.396 Sq Ft.											

CALCULATIONS FOR AIR TESTS.

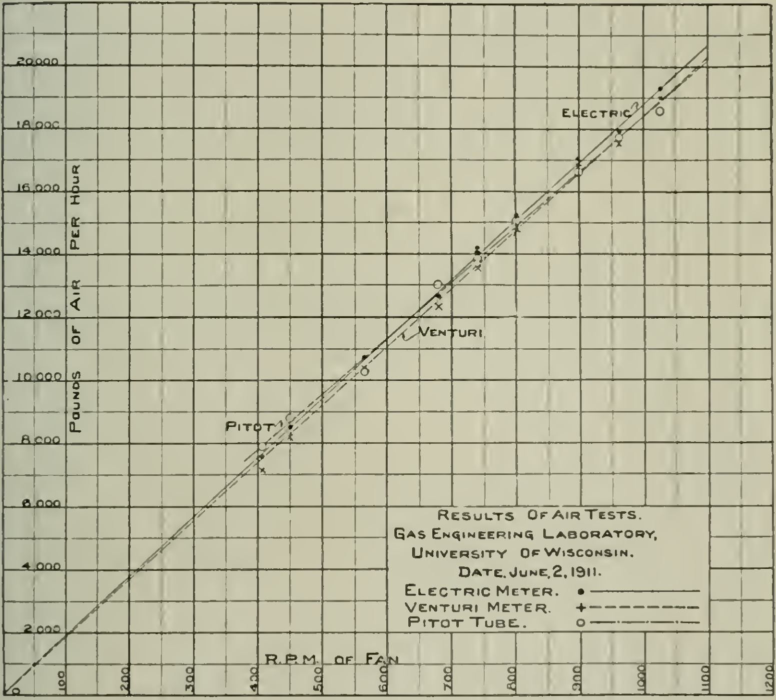
University of Wisconsin, Gas Laboratory, June 2, 1911.

RESULTS.

Simultaneous readings were taken on the three meters at different fan speeds. Great care was necessary in reading the water columns of the Pitot and Venturi meters because of small fluctuations in fan speed, but the observations were made with the greatest degree of refinement possible with the apparatus. The observations and computations are recorded in the following data sheets and the comparative results are plotted in Fig. 9.

The close agreement of the results obtained in the measurement of a common quantity by these three fundamental and independent methods of measurement, with independent observations taken for each, forms, from a scientific standpoint, a very interesting proof of the correctness of the several theories involved. The test also shows that any of the three meters will give satisfactory results, provided they are properly used under sufficiently favorable conditions, and provided the observations are made with a sufficient degree of refinement.

Fig. 9.

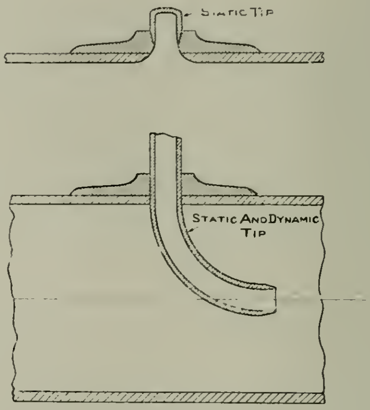


It is evident, however, that by the electric method results can be obtained directly from simple observations made with instruments of only moderate refinement that compare most favorably with those that can be obtained by the Pitot or Venturi meters after laborious computations based on observations carefully taken from refined instruments.

THE COMMERCIAL MEASUREMENT OF GASES.

Although the wet and dry displacement meters and the rotary meters give satisfactory results for commercial purposes under some conditions of service, their application is very limited by conditions of pressure, temperature, capacity, etc., and there is a vast number of instances in which air and gases must be measured by some form of the meters described in the preceding pages. It is in most cases highly desirable to use some form of meter that will give reliable results automatically under continuous service conditions, independently of fluctuations in pressure and temperature, and that will record the flow either on a graphical chart or on a totalizing dial, or both.

FIG 10.

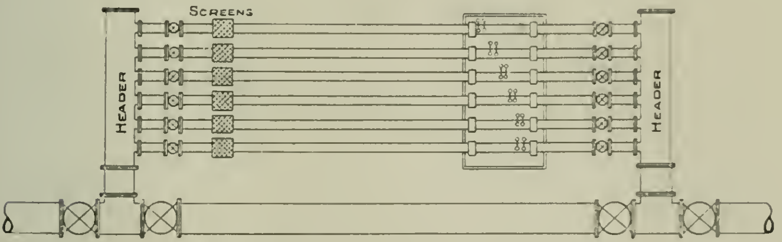


PITOT TUBE.

The Pitot tube has been very successfully applied to the measurement of high pressure natural gas where a comparatively small drop in pressure can always be made use of to increase the velocity of the gas through a restricted portion of the transmission line and thus to increase the velocity head to an amount that can be accurately read on a water column.

When thus used the pressure and velocity tubes are inserted permanently in a comparatively small pipe having a smooth inner surface as shown in Fig. 10. A considerable length of this smooth restricted passage is provided in the approach to the measuring tubes, and fine screens are inserted ahead of them to prevent foreign substances from clogging the openings. The static head is indicated by a high-grade Bourbon gauge and the velocity head is observed in a water column. The scale is adjustable so that the zero can be set at the height of the water in the well to which the static pressure pipe leads. The observation of two water columns is thus avoided. Although the range in rate of flow of gas under any given pressure and temperature condition which can be accurately measured with one such Pitot tube unit, is less than one to three, the working range of a measuring station can be very effectively increased by putting several such units in parallel, as shown in Fig. 11.

FIG. 11.



Measuring station of parallel Pitot tube units.

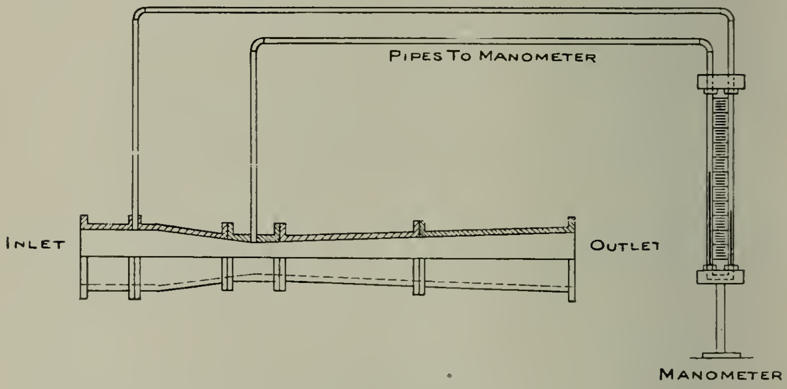
Careful observations of pressure and velocity head are made at intervals sufficiently short to obtain correct averages. Very thorough and accurate calibrations have been made on these units from which have been established coefficients for each tube. By means of these coefficients and of tables for the reduction to a standard pressure and temperature each set of observations is reduced to standard cubic feet.

The Venturi meter, as shown in Fig. 12, has been used with some success in the practical measurement of gases. A paper by Mr. E. P. Coleman, published in the *Transactions of the American Society of Mechanical Engineers*, Volume 28, describes some interesting tests with such a meter.

Patient and consistent efforts have been made to develop devices which can be used in connection with Pitot or Venturi meters to give continuous graphical or integrated results. The fundamental difficulty in accomplishing this lies in the fact that the power available for operating a recording or totalizing device is always very small, only that due to a few inches of water at the best. And even if the velocity head in a Pitot meter or the differential pressure in a Venturi throat could be satisfactorily recorded or integrated, attachments must be added to the device to correct the readings to a standard temperature and pressure if the temperature and pressure of the gas flowing through the meter are to vary more than a negligible amount.

It is noted that both these methods of measurement, when reduced to commercial form, involve a pressure drop in the gas through a restricted area. In the Venturi meter the increased velocity due to this drop is computed from the measured pressure drop which is assumed to take place adiabatically; while in the Pitot tube the velocity is increased to a value where it can be measured directly and accurately. They both measure the velocity of gas through a given area of passage and thereby measure the rate of flow in volumetric units. The electric meter differs from the other two in that it determines the quantity of gas by measuring the electrical energy required to maintain a constant small difference in temperature of the gas between its entrance to and its exit from the meter. The amount of heat necessary to increase the temperature of a given portion of gas depends on the mass, or amount of "stuff" in the given portion, and upon its specific heat. It does not depend upon the volume which the portion happens to occupy at the time of measure-

FIG. 12.



VENTURI METER.

ment. The meter is therefore independent of the volume, or, in other words, of the pressure and temperature of the gas, so long as the specific heat remains constant. The experiments to be described are of particular interest in that they show that the specific heat of natural gas is constant within the very considerable range of pressures over which the tests extended. The same is true with regard to the tests on illuminating (artificial) gas, and on air, though with these the pressure range was not as great as it was in the natural gas experiments.

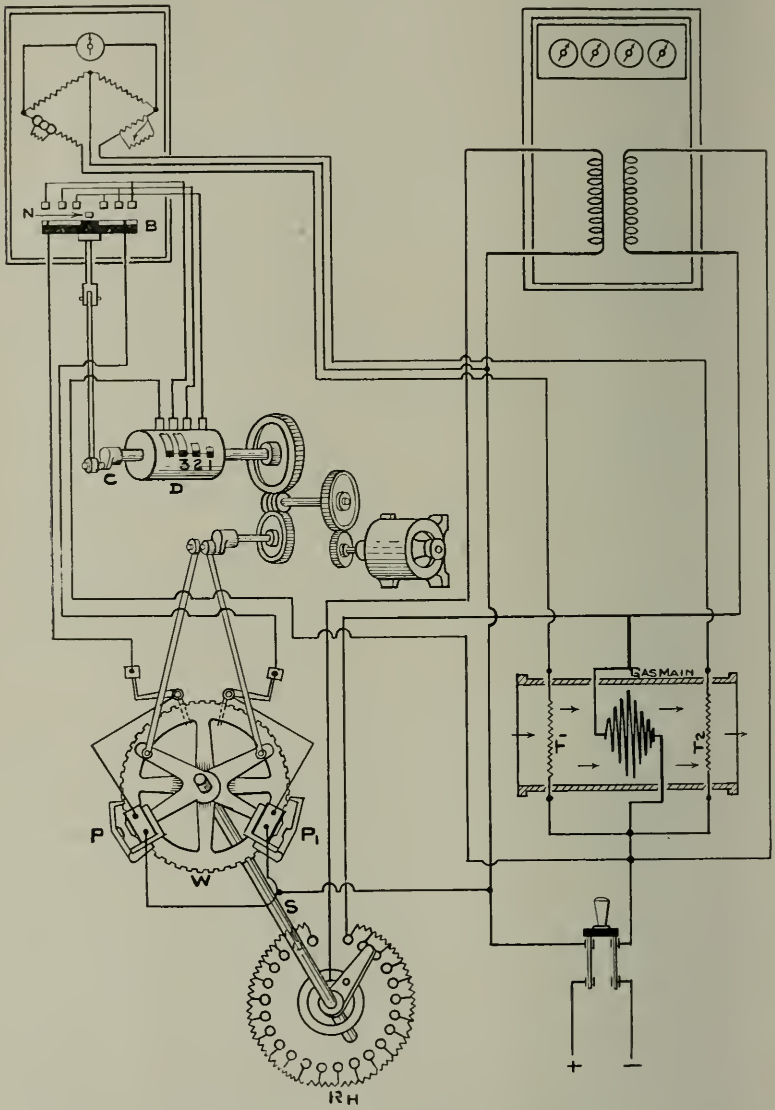
In its original form the electric meter was a means of supplying a known constant energy to the gas and of graphically recording the resultant rise in temperature. In its present commercial form it automatically maintains a constant temperature increase in the gas and measures the energy required to produce this increase. Temperature difference on the two sides of the heater can be maintained constant to a high degree of accuracy by a simple and reliable device in connection with resistance thermometers which regulates the electric energy in the heater. Since the specific heat of a unit weight of the gas remains constant for varying temperatures and pressures, and since the temperature rise is maintained constant, the weight of gas flowing must be directly proportional to the electrical energy dissipated in the heater. Thus with this meter the only quantity necessary to be measured is electrical energy, and this can be done accurately and reliably by means of well-developed commercial wattmeters of either the graphical or integrating type. Also, since the weight of gas is directly proportional to this electrical energy, the wattmeter dials may be made to read directly in standard cubic feet at any desired pressure and temperature.

Thus the electric method lends itself easily and simply to a commercial design that gives continuous results in either a graphical or integrated form, directly in standard units, obtained without the necessity of calculation. The accuracy of the measurement is as great as that with which electrical energy can be measured.

THE COMMERCIAL ELECTRIC METER.

Fig. 13 is a diagrammatic sketch of the electric meter in the present commercial form. It differs from the manually controlled meter before described only in that it is provided with an automatic device for maintaining a constant temperature difference in the gas on opposite sides of the heater unit. An increase

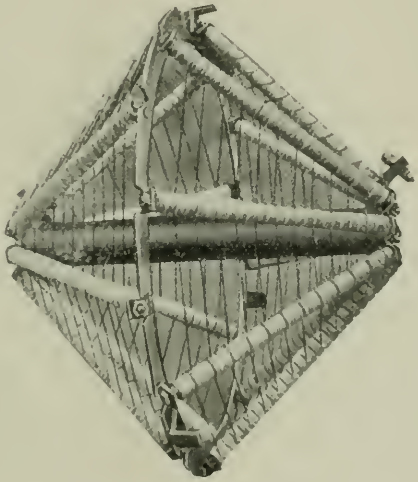
FIG. 13.



Diagrammatic sketch of automatic electric meter.

in rate of flow of gas through the meter will cause the thermometer T_2 to become less than its normal two degrees warmer than thermometer T_1. This decreases the resistance of T_2 with respect to T_1 and causes a deflection of the galvanometer needle N to the right, the amount of the deflection depending upon the amount of change that has occurred in the rate of flow. On the shaft S of the rheostat R_h, which is in series with the heater, is a toothed wheel W. At the right and left edge of this toothed wheel two pawls, P and P_1, move with a continuous reciprocating motion through an arc having the length of three teeth on the edge of the wheel. A one-eighth horsepower motor on the front of the panel runs continuously at constant speed and drives the bell cranks carrying these pawls. It also drives a contact drum D and a crank C, which causes a bar B to clamp the galvanometer needle N at intervals of a few seconds between a series of metallic contacts. If the change in gas flow has deflected the galvanometer needle so that it is clamped between the right-hand upper and the lower contact, the pawl P_1 will engage the toothed wheel when segment No. 3 on the revolving drum engages with its contact finger and energizes the magnet on P_1. This contact will occur when the pawl is at the bottom of its stroke, and the drum segment will keep the pawl engaged until it reaches the top of its stroke. Thus the deflection of the needle three divisions to the right has caused the

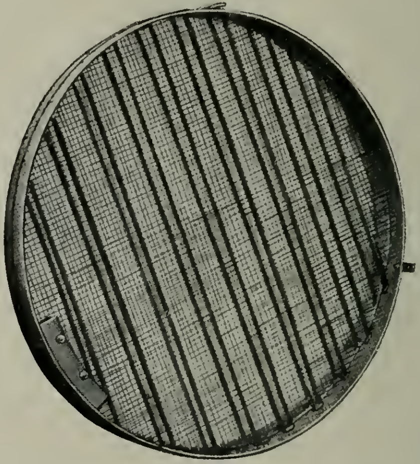
FIG. 14.



Heater unit for electric meter.

rheostat arm to be moved so that the heater energy has been increased three steps. Had the flow of gas decreased, the deflection of the needle would have been to the left and the heater energy would have been decreased. Had the deflection of the needle been only two divisions, the heater energy would have been changed two steps, etc. So long as the gas flow remains constant the galvanometer needle remains balanced and the heater energy remains unchanged. Thus the energy in the heater is automatically regulated to maintain a constant temperature difference of about two degrees F. in the gas. This accomplished, it only remains to measure the electrical energy in the heater, which is done by an integrating wattmeter, as shown in the diagram, or by a graphical wattmeter which traces on a record roll a continuous curve showing the rate of flow of gas at any time. Since the weight of gas flowing through the meter is always directly proportional to the watts dissipated in the heater, the wattmeters can be made to read directly in any standard weight units, such as pounds, or standard cubic feet of gas at atmospheric pressure and 60 degrees F., and they will always give results directly in these units, regardless of the actual pressure and temperature of the gas as it flows through the meter.

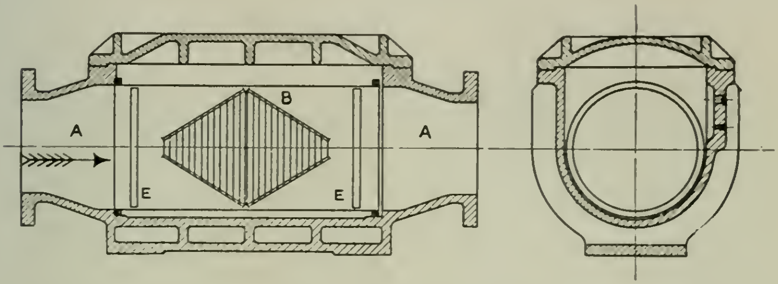
FIG. 15.



Resistance thermometer unit for electric meter.

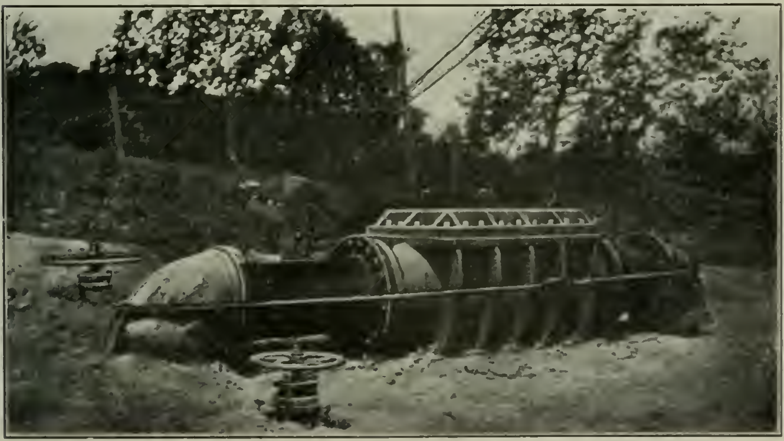
Fig. 14 is a photograph of a typical heater unit, in which the resistance wire is wound on a double-ended cone. Fig. 15 is a thermometer screen showing how the resistance material is distributed over the area of the pipe. Fig. 16 shows in section the heater and thermometer units assembled in the casing. Inside of the pressure casing is a light inner casing in which the units are assembled, and around which is a gas jacket to reduce loss of heat by radiation to a minimum. As the temperature of the gas is raised only 2 degrees F. this precaution is of little importance and has been dispensed with in some cases. However, the construction described is very convenient from an op-

FIG. 16.



Sectional view of electric meter casing, showing heater and thermometer units in position.

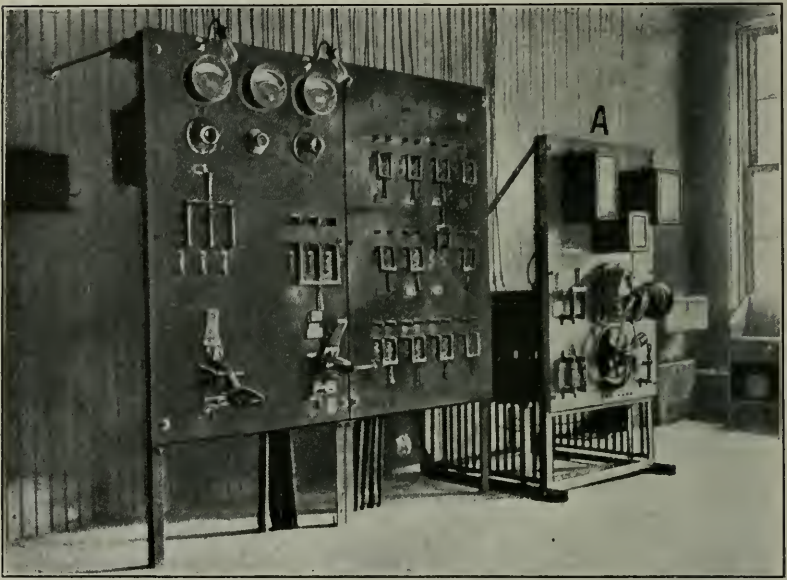
FIG. 17.



Electric meter installed in 10-inch suction pipe to natural gas pumping station.

erating standpoint, and incidentally provides the jacket space. The pressure casing is so designed that the cover can be removed and the inner casing with the units taken out for cleaning. Fig. 17 is a photograph of a meter casing in a field in a suction line to a natural gas pumping station. Electric wires lead from this casing to the recording panel, which is placed in any convenient location. Fig. 18 shows at *A* the recording panel having mounted on it the graphical and integrating wattmeter, the automatic control device, and the control switches.

FIG. 18.



Electric meter recording panel installed alongside of switchboards in lighting plant.

CONDITIONS WHICH AFFECT SPECIFIC HEAT.

If a meter is to give satisfactory results for commercial uses the measurement must be based upon some property of the gas which, in the operation of the gas plant or pipe line, will not be so altered as to affect the results. Since with the electric meter the accuracy of the measurement depends entirely upon the specific heat of the gas, its accuracy will be affected only by those conditions which change the specific heat of the standard unit of measurement.

That the specific heat of a standard cubic foot of gas is independent of the actual pressure and temperature of the gas within any ordinary working limits is not only in accordance with well-established theory, but it has been shown conclusively by tests that will be described later.

It is evident that a variation in composition of the gas will affect the specific heat somewhat. That this effect is in most cases entirely negligible is shown by the following comparisons.

Two typical analyses for artificial gases in a city plant are:

	Water Gas.	Coal Gas.
Co_2	3.8	2.2
CnH_2n	12.3	3.3
O	0.6	0.5
CO	30.4	6.9
H	33.3	50.6
CH_4	14.4	34.2
N	5.2	2.3

From these analyses are computed the values of specific heat of different mixtures of water gas and coal gas as given below. The values of specific heat are in B.T.U. per degree F. for a cubic foot of gas at 14.804 pounds absolute pressure and 60 degrees F.

Water Gas Per Cent.	Coal Gas Per Cent.	Specific Heat
100	0	.02094
90	10	.02096
80	20	.02098
70	30	.02100
60	40	.02102
50	50	.02104
40	60	.02106
30	70	.02108
20	80	.02110
10	90	.02112
0	100	.02114

The following table shows a typical variation in composition from day to day of mixed crude oil gas and carburetted water gas. To this table have been added the computed values of specific heat in B.T.U. per degree F. for a cubic foot of gas at 14.696 pounds absolute pressure and 60 degrees F.

Date June	CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2	CP	BTU	Sp. Gr.	Sp. Ht
11	3.4	9.2	0.4	11.0	37.2	32.9	5.9	21.8	703	.518	.02168
12	3.5	9.7	0.4	9.8	36.6	33.2	6.8	22.9	710	.522	.02174
14	3.4	10.2	0.4	10.0	36.3	33.6	6.1	22.9	724	.523	.02182
15	4.0	10.0	0.4	10.6	35.8	32.5	6.7	21.4	708	.535	.02180
16	3.5	9.3	0.4	10.2	38.3	31.9	6.4	21.6	696	.512	.02167
17	3.4	9.6	0.2	10.0	36.7	34.6	5.5	20.9	724	.515	.02182
18	3.6	10.0	0.4	10.0	37.2	32.3	6.5	21.5	709	.521	.02173
19	4.0	9.6	0.2	10.6	34.5	34.0	7.1	22.1	712	.540	.02182
21	3.8	9.7	0.2	10.0	35.6	33.7	7.0	21.7	712	.531	.02182
22	3.7	9.7	0.4	10.2	37.2	32.9	5.9	22.0	710	.519	.02174
Avg.	3.63	9.70	0.34	10.24	36.54	33.16	6.39	21.88	710.7	.5236	.02176

Mean of ten values of specific heat computed from individual analyses .... .02176

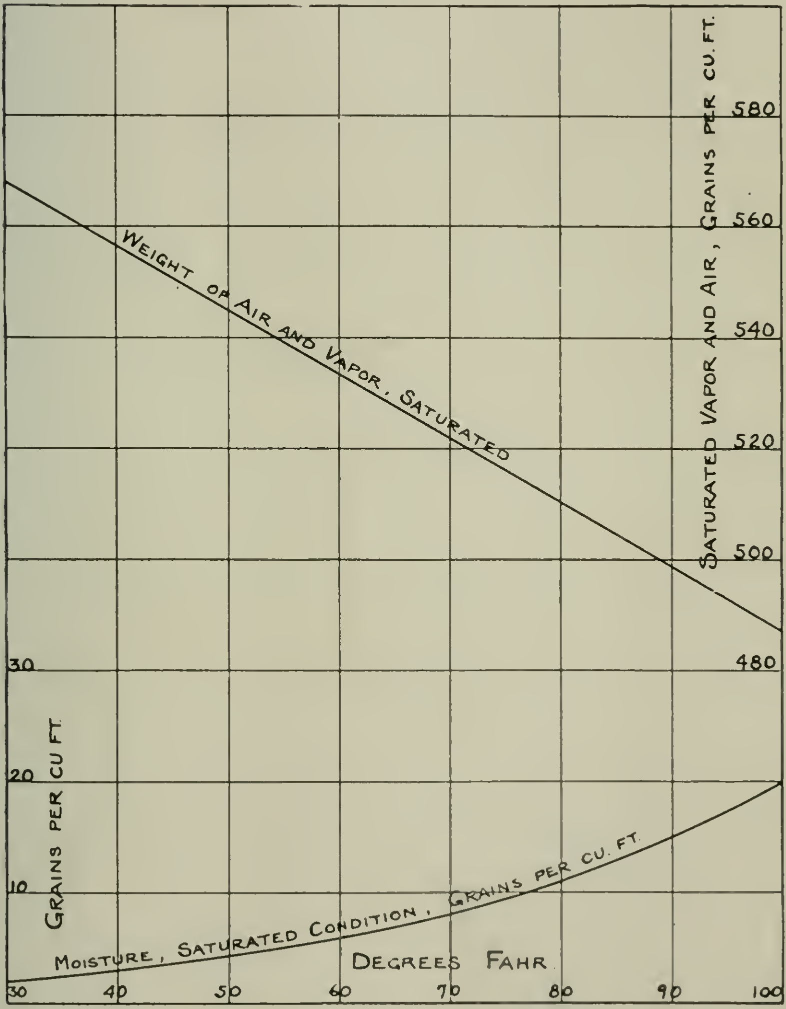
Maximum variation of specific heat computed for individual analyses from the specific heat computed for the average analysis .... 0.4 per cent.

Two typical analyses of natural gas, with their corresponding computed specific heats are:

CH_4..........	79.95	88.74
C_2H_4..........	15.13	10.66
N............	4.90	.22
O............	.02	.16
CO_2..........	.....	.22
Specific heat per cu. ft. at 60° F., and 15.025 lbs. absolute pressure	.02599	.02609

A certain amount of water vapor forms a part of almost all gases, including atmospheric air. The curves in Fig. 19 show the weight of water vapor in air at different temperatures and at 100 per cent. humidity. This can be expressed as a percentage of the total weight of air and vapor. Thus at 60 degrees F., 30-inch barometric pressure, and 100 per cent. humidity, the weight of a cubic foot of air and vapor is 533 grains, and from the lower curve it is seen that it is possible under saturated conditions for the cubic foot of space to hold 5.6 grains of water vapor. The water might then amount to 1.05 per cent. of the weight of the air, and as the specific heat of water vapor is approximately twice that of air, the correction due to fully-saturated water vapor would amount to about one per cent. This correction can be made by the use of curves similar to those shown, on the basis of an assumed or an ascertained humidity.

FIG. 19.



Curves showing weight of water vapor in air at different temperatures and at 100 per cent. humidity. Note that the two curves are drawn to different scales.

This is rarely 100 per cent., the normal relative humidity being more nearly 50 per cent., and the correction, therefore, about one-half of one per cent. If the gas is over-saturated, and the water is carried in it mechanically as a fog or mist, the evaporation of this by the meter itself, of course, interferes with making accurate measurements. In such cases it is necessary to transform the fog or mist into dry vapor by the introduction of heat to the gas before it enters the meter.

SOME PRACTICAL REQUIREMENTS OF CONTINUOUS RUNNING METERS.

Whenever the measurement of gas plays an important part in the operation of a plant it is necessary to know that the meters are measuring accurately, and they are inspected at regular intervals and checked whenever possible. With the electric meter it is possible to check the condition of the parts inside the gas main from the recording panel without opening up the meter. If the heater circuit is broken and the temperature difference resistance is shorted out while gas is flowing through the meter, the two thermometer units will come to equal temperatures and the galvanometer needle will come to a balance in its central position. Should anything have happened to change the thermometers, which are the basis of measurement, the trouble is thus easily detected. A small rheostat is provided in series with one thermometer to bring them back to a balance if they should be slightly unbalanced.

Deposits on the inner parts of a meter are always liable to occur to some extent, and these must not affect the accuracy of measurement. Such deposits on the heater unit in the electric meter cannot affect the accuracy, since the heater is only a means of dissipating energy and this energy is measured by wattmeters independently of the resistance or surface of the heater unit. Moderate deposits on any of the inner parts of the meter will tend to make the units somewhat slower in their response to changes in flow, but will not affect the accuracy of measurement. The heat is all dissipated within the meter casing and must necessarily all go into the gas.

A meter designed for continuous service under ordinary operating conditions must have as large a range as possible between maximum and minimum rates of flow at which it will measure accurately. The electric meter has in general a range of about 15 to 1 in capacity. If it is desired to measure low rates of flow accurately with a high capacity meter, two temperature difference resistances are provided instead of one. By shifting a resistance plug and dividing the wattmeter readings by the ratio of the two temperature differences, the possible accurate range of a single unit can be increased to about 60 to 1.

If a meter is to run continuously the cost of operation must not be excessive. With the electric meter about one kilowatt-hour of energy is required to measure 75,000 cubic feet of free gas. Assuming that one kilowatt-hour can be obtained from 50 cubic feet of gas, the cost of operation of the meter is equivalent to less than one-tenth of one per cent. of the gas that it will measure. As this percentage is well within the limit of the possible accuracy of measurement, the cost of operation is seen to be very moderate. Since the results are graphically recorded or integrated, no observations need to be made and the labor cost for care is reduced to a minimum.

COMPARATIVE TESTS OF COMMERCIAL METERS.

I. *With Artificial Gas and Air.*

Some very interesting tests have been made to check the accuracy of the electric meter against the wet displacement meter as a standard in low-pressure artificial gas work, and against the Pitot tube as a standard in high-pressure natural gas measurement.

During the development stages tests were made with the electric meter in series with a wet displacement meter with both air and illuminating gas in the Third Ward Plant of the Milwaukee Gas Light Company. This meter was of the constant energy, variable temperature type. Fig. 20 is a portion of a graphical record of the test showing rates of flow varying from 17,000 to 75,000 cubic feet per hour. The energy input during this test was approximately 1.15 kilowatts.

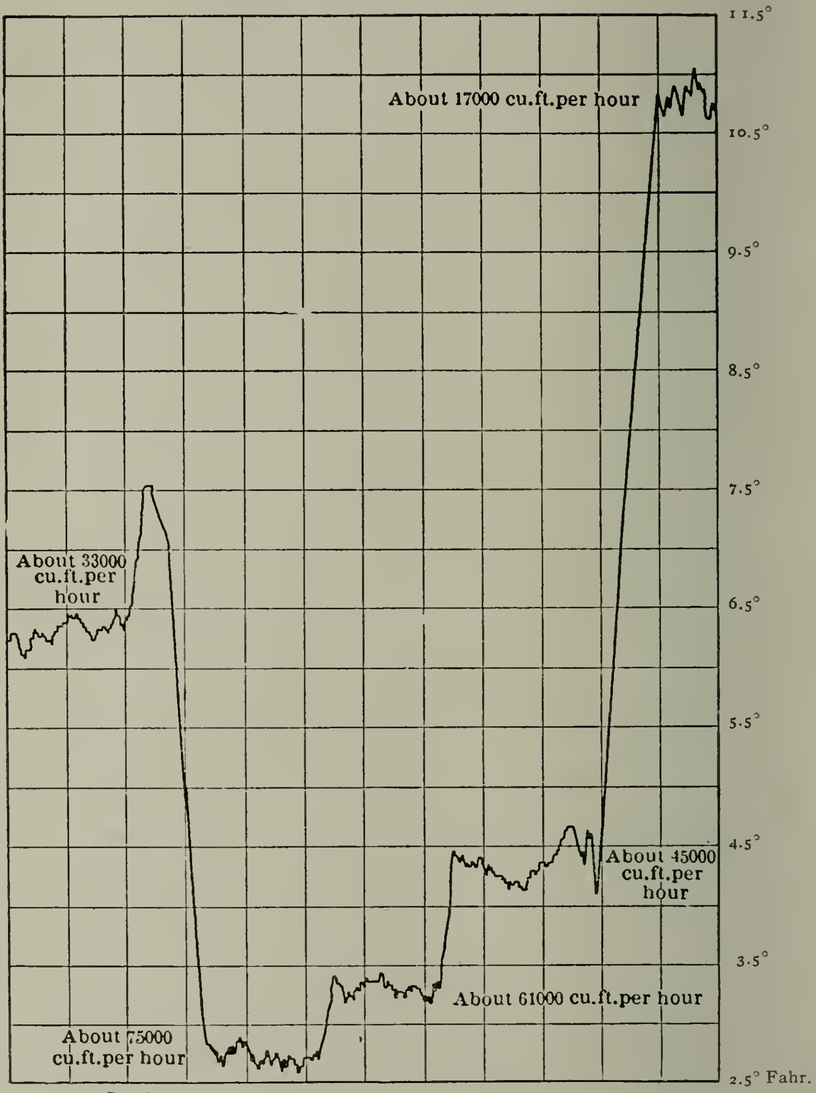
Let G = cubic feet of gas flowing per hour.
E = energy supplied in kilowatts.
T = temperature difference in degrees F.
S = specific heat per cubic foot.

Then

$$GST = 3412\,E \text{ and } G \times \frac{T}{E} = \frac{3412}{S} = \text{a constant.}$$

If, then, values of G, or the cubic feet of gas per hour obtained from the wet meter, are plotted as ordinates, and values of $\frac{T}{E}$, or the temperature rise per kilowatt input to the electric

FIG. 20.

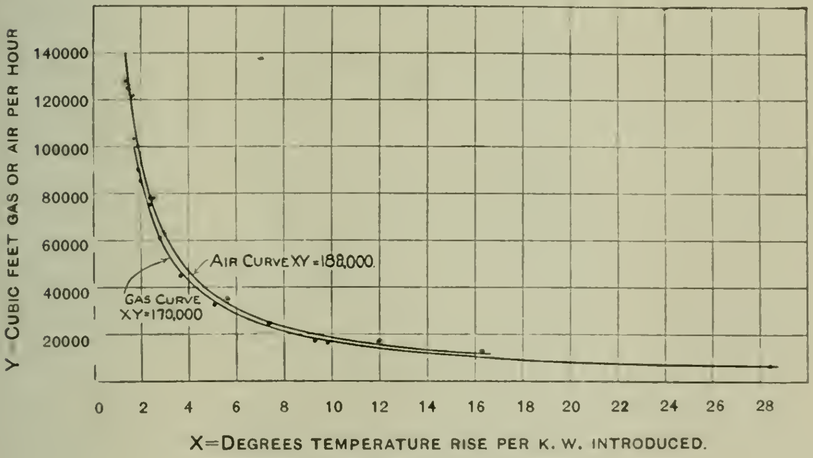


Graphical record of temperature difference with constant energy input.

meter, be plotted as abscissæ, the resultant curves should be rectangular hyperbolas. That they are asymptotic to the co-ordinate axes is apparent because, when an infinitely great amount of gas is being heated, any finite input of heat will produce only an infinitely small rise of temperature, and, on the other hand, when the amount of gas becomes infinitely small, a finite input of heat will cause an infinitely great rise in temperature.

It is obvious from the curves shown in Fig. 21 which were plotted from the experimentally determined points for both the gas and air tests, and which are true hyperbolas, that the results obtained are in complete accord with well-established theory.

FIG. 21.



Rectangular hyperbolas plotted from gas and air tests.

For the gas curve it is found that the constant $\frac{GT}{E} = 170{,}000$, while the corresponding constant for air $= 188{,}000$. Since $\frac{GT}{E} = \frac{3412}{S}$, it follows that the specific heat of the gas during the test was $\frac{3412}{170000}$, or 0.0201 B.T.U. per cubic foot, and that the specific heat of the air was $\frac{3412}{188000}$, or 0.0181.

The conditions during the gas test were as follows: Barometer 29.8 inches, gas pressure 6 inches water, average temperature of gas measured in the wet meter 59 degrees F. If the specific heat thus obtained is reduced to standard conditions of 32 degrees F. and 29.9 inches mercury, then $S = 0.0210$.

which is to be compared with the calculated value for specific heat of 0.0211 from the analysis of the gas given below.

	Volume cubic feet	Weight per cu. ft., lb.	Total weight lb.	Specific heat per lb.	Specific heat per cubic ft.
CO_2	0.04	0.11637	0.004658	0.216	0.00100
C_2H_4	0.11	0.0741	0.00815	0.404	0.00329
O_2	0.001	0.08463	0.00085	0.217	0.00023
CO	0.331	0.07407	0.02450	0.245	0.00600
CH_4	0.1761	0.04324	0.00746	0.593	0.00442
H_2	0.303	0.00530	0.00160	3.409	0.00546
N_2	0.0389	0.07429	0.00289	0.244	0.00071
					0.02111

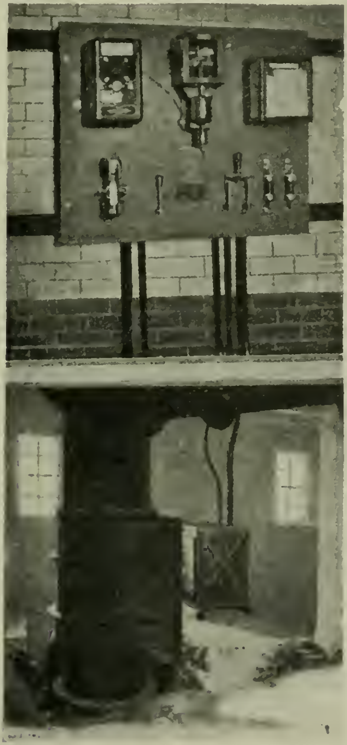
During the air tests the conditions were as follows: Barometer 29.75 inches, air pressure 6.5 inches water, average temperature of air measured in wet meter 60 degrees F. Reducing the value for specific heat obtained by the test under these conditions to standard conditions of 32 degrees and 29.9 inches mercury, $S = 0.0191$. This is to be compared with the accepted specific heat of air under these conditions, or 0.0192 B.T.U. per cubic foot. Since the specific heat of air is well known and since the wet meter is a very accurate device at the conditions under which the measurements were made, these tests provide the very best evidence of accuracy of the electric method of measurement. The wet meter was put in first-class condition and thoroughly tested and regulated before the tests were made.

Fig. 22 shows an installation of the electric meter in the West Side Plant of the Milwaukee Gas Light Company designed to measure continuously and to give both graphical and integrated records of the total supply of artificial gas to the city of Milwaukee. The meter casing replaced a short vertical section of 30-inch pipe line in the basement of the pumping station leading from the pumps to the distributing lines of the city, while the recording panel, having mounted on it the recording instruments and control switches, is located on the wall where it can be conveniently operated and read from the pumping station floor. This meter has a maximum capacity of 3,000,000 cubic feet of free gas per hour and an accurate minimum capacity of 50,000 cubic feet. Fig. 23 is a portion of a graphical record made by this meter showing the peak in total output caused by the cooking load at noon. The steps in the sides of this peak show the sudden changes in rate of flow caused by the operation of the control valve in the pump discharge.

II. *Tests With Natural Gas.*

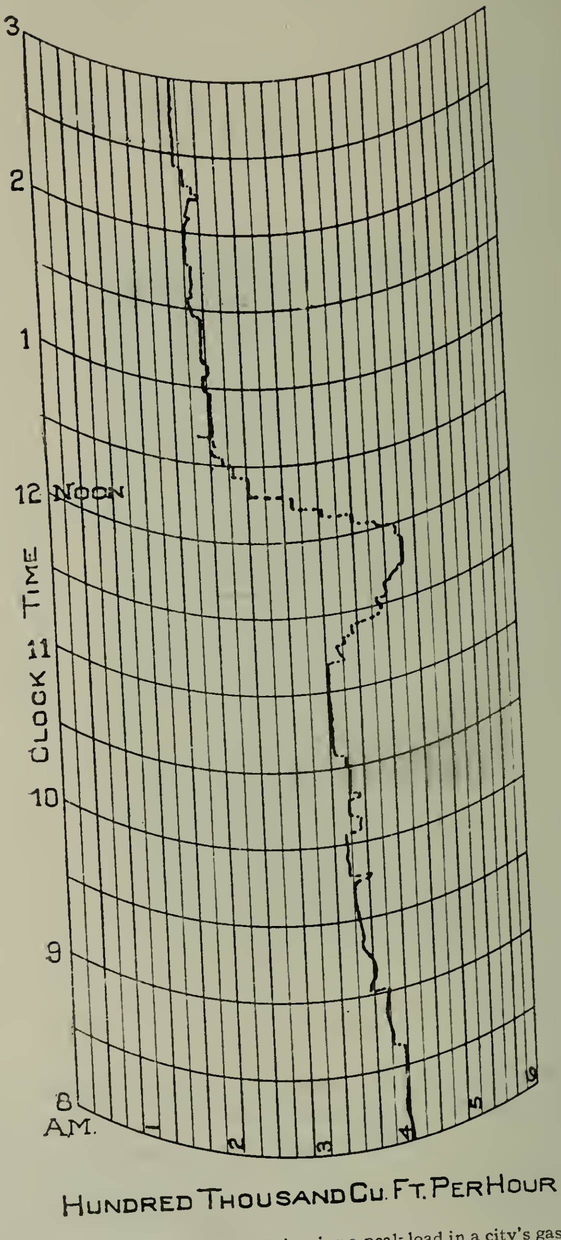
At the Brave Pumping Station of the People's Natural Gas Company of Pittsburgh is installed an electric meter for the continuous measurement of natural gas between the wells and the pumps. This meter gives in the office of the pumping station a continuous graphical record as well as integrated values of the flow of gas through the line in which it is installed, directly in standard cubic feet, at 15.025 pounds absolute pressure and

FIG. 22.



Electric meter installed in basement of pumping station, with recording panel on main floor above.

FIG. 23.



Graphical record from electric meter showing a peak load in a city's gas supply.

60 degrees F., although the pressure of the gas varies from 50 to 200 pounds gauge, and the temperature varies with weather conditions.

The meter casing is installed in a field just above the level of the ground, immediately between two elbows and close to gate valves, and is in a 10-inch suction line within about 200 feet of the suction header of the pumping station, as shown in Fig. 17. The recording panel is installed, as shown in Fig. 18, alongside of the switchboards in the lighting plant from which the meter receives its supply of energy. The meter has a maximum capacity of 750,000 cubic feet of free gas per hour and an accurate minimum capacity of 12,500 cubic feet. It was designed to give readings directly in standard units, the specific heat of which was computed from an analysis assumed from an average and to correspond to the standard pressure and temperature stated above. This installation has afforded an unusual opportunity for checking the accuracy of the meter on account of the very wide variations in pressure and rate of flow of the gas through the line in the ordinary operation of the system, and also because there is installed at Bula a very complete and thoroughly calibrated Pitot tube station, similar to that shown in Fig. 11, one tube of which is in the same line with the electric meter. The two meters can thus be run in series, although they are separated by about one and one-half miles of 10-inch pipe. Readings of pressure and velocity head are taken on the Pitot tube every fifteen minutes, day and night, and from these readings values of gas flow in standard cubic feet are obtained by the use of carefully prepared tables. As these tables reduce the Pitot tube readings to the same standard units in which the electric meter was designed to read, the results are directly comparable.

Very thorough tests were made on the electric meter under service conditions to determine the degree of accuracy with which it would give continuous results directly in standard cubic feet with variable pressures, temperatures, and rates of flow as compared with the results obtained by very frequent and careful observations on the Pitot tubes, and also to learn whether all the parts would stand up satisfactorily against wear and the action of the gas.

The following table shows the hourly results of a comparative test of 22 hours' duration. During a large part of this test the rate of flow was kept nearly constant and the temperature of the gas remained about the same, but the pressure varied from 72 to 123 pounds gauge. The values of cubic feet for each hour are obtained from the chart by averaging the curve traced by the meter; from the integrating meter by subtracting the dial reading at the beginning of the hour from that at the end; and from the Pitot tube in the manner described above.

Hour	Cubic feet each hour			Total cubic feet at end of each hour		
	Chart	Integrating meter	Pitot tube	Chart	Integrating meter	Pitot tube
8– 9	397500	400000	400297	397500	400000	400297
9–10	398500	398000	394027	796000	798000	794324
10–11	370000	374000	373731	1166000	1172000	1168055
11–12	376500	377000	380800	1542500	1549000	1548855
12– 1	361500	364000	367726	1904000	1913000	1916581
1– 2	370900	377000	377694	2274900	2290000	2294275
2– 3	381200	387500	386103	2656100	2677500	2680378
3– 4	380900	386500	387815	3037000	3064000	3068190
4– 5	382600	384000	387229	3419600	3448000	3455419
5– 6	385510	388000	389052	3805110	3836000	3844471
6– 7	391250	388000	392161	4196360	4224000	4236632
7– 8	395000	391000	394654	4591360	4615000	4631286
8– 9	394500	392000	392416	4985860	5007000	5023702
9–10	397500	398000	392245	5383360	5405000	5415947
10–11	387000	383000	385383	5770360	5788000	5801330
11–12	388000	387000	387104	6158360	6175000	6188434
12– 1	378000	373000	386983	6536360	6548000	6575417
1– 2	439500	436000	435416	6975860	6984000	7010833
2– 3	447000	446000	445945	7422860	7430000	7456778
3– 4	463000	459000	465896	7885860	7889000	7922674
4– 5	465000	464000	467240	8350860	8353000	8389914
5– 6	407500	411000	394886	8758360	8764000	8784800

After this run a 45-day test was made on the two meters under service conditions, during which time but very few interruptions occurred in the gas flow. Readings were taken on the Pitot tube as before, and results were obtained from the electric meter by means of the continuous records and by reading the integrating instrument at intervals of three hours. The following is a sample log sheet for a 24-hour period of the test:

NOON APRIL 26th TO NOON APRIL 27th, 1911.

Time	Integrating meter reading	Cubic feet integrating meter	Cubic feet chart	Cubic feet Pitot tube	Pressure		Temp.	
					Brave	Bula	Brave	Bula
12:00	2498.0							
3:00	2603.6	1056000	1030800	1056539	134	140	47	46
6:00	2714.3	1107000	1073400	1115176	157	161	47	43
9:00	2831.7	1174000	1134000	1160802	156	160	47	43
12:00	2965.0	1333000	1321200	1311671	162	167	47	43
3:00	3086.7	1217000	1230600	1226774	162	166	47	42
6:00	3215.0	1283000	1302900	1310577	114	124	47	40
9:00	3375.0	1600000	1631400	1614811	113	125	47	40
12:00	3523.2	1482000	1479000	1480000	135	143	47	46
Totals		10252000	10203300	10276350				

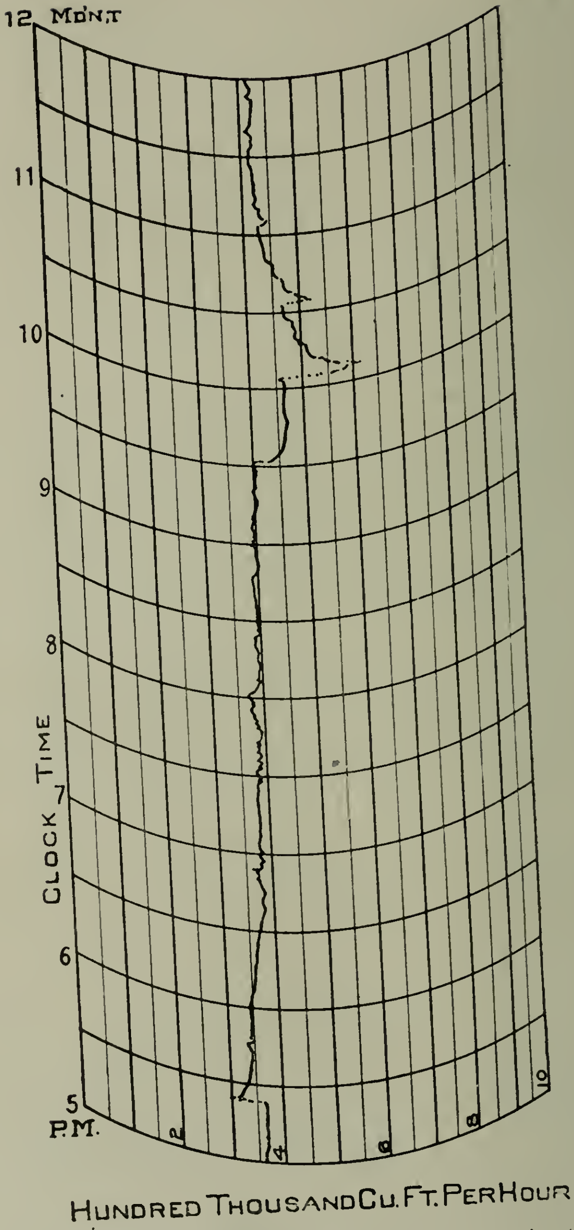
Fig. 24 is a portion of the graphical chart made by the electric meter for the same period, showing some sudden changes in rate of flow, and Fig. 25 shows the variations in pressure as plotted from observations made at the Pitot tube.

During the 45-day test the rate of flow varied from 90,000 to 640,000 cubic feet per hour, the pressure of the gas varied from 46 to 185 pounds gauge, and the temperature varied from 45 to 65 degrees F.

In order to study the comparative results obtained from the two meters under all the different conditions existing during the test a graphical chart was plotted, showing total comparative results obtained from the two meters during each three-hour period throughout the test. Fig. 26 shows a portion of this chart.

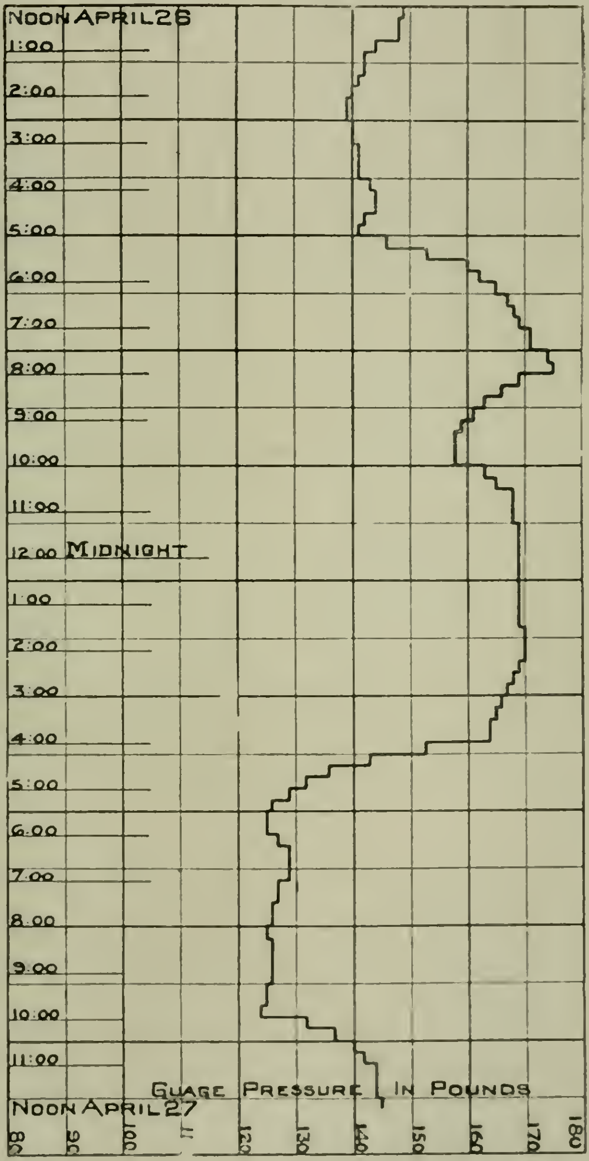
It is seen from this chart that the results of the two meters varied slightly for short periods, but most of these cases are easily explained by the fact that there were several thousand feet of 10-inch pipe between the meters, that the flow of gas was controlled by sudden changes, sometimes at Brave and sometimes at Bula, and that during some of these periods the pressure of the gas was increasing or decreasing over quite wide ranges. As shown by the following total results for the whole test, these slight errors averaged out in longer periods of time, and the two methods of measurement gave practically identical results in both the short and the long tests.

FIG. 24.



Graphical record from electric meter showing sudden changes in rate of flow.

FIG. 25.



Graphical log of gas pressures for a 24-hour period of the test at Brave, Pa.

The following is a summary of the results of the tests:

22-HOUR TEST, APRIL 9TH AND 10TH, 1911

Total standard cubic feet of gas for 22 hours by Pitot tube....	8,784,800
Total standard cubic feet of gas for 22 hours by electric meter	8,764,000

$$\frac{8{,}784{,}800 - 8{,}764{,}000}{8{,}784{,}800} = 0.2\% \text{ difference.}$$

ENDURANCE TEST, APRIL 17TH TO JUNE 3RD, 1911

Total standard cubic feet of gas by Pitot tube..................	337 546,182
Total standard cubic feet of gas by electric meter.............	336,732,018

$$\frac{337{,}546{,}182 - 336{,}732{,}018}{337{,}546{,}182} = 0.2\% \text{ difference.}$$

In order to make the test complete and the results more conclusive, the gas was analyzed during the test and the specific heat of the standard cubic foot was computed from this analysis. Although the actual composition of the gas was found to be considerably different from that assumed for the design of the meter, the values of specific heat as computed from the two analyses were almost identical.

After the tests were completed the heater and thermometer units were removed from the casing and thoroughly inspected. They were found to be in perfect condition, and the only deposits to be found anywhere inside the casing were a very thin coating of fine dark-brown powder, almost dry, and a few finely divided pieces of scale. The recording instruments and control device were also found to be in perfect condition.

SUMMARY.

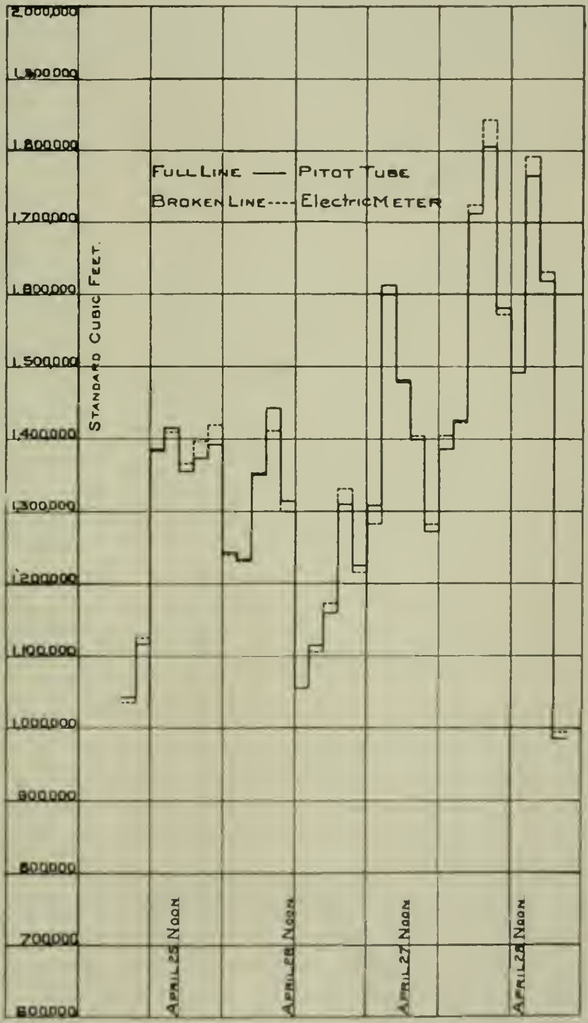
The discussions and tests in the preceding pages may be summarized as follows:

I. Formulæ for theoretical flow through pipes are useful for the design of pipe lines, but not for the measurement of flow through existing lines.

II. The Pitot, Venturi, and electric meters will all give accurate and reliable results when properly used under favorable conditions and when observations are taken with a sufficient degree of refinement in methods.

III. The electric meter will give continuous results, either graphical or integrated, even under severe commercial conditions of operation, that compare most favorably with the best that can be obtained with other forms of direct reading meters or by frequent observations on Pitot tubes and the use of tables and

FIG. 26.



Portion of graphical chart showing comparative total results for each three-hour period for four days of 45-day test at Brave, Pa.

coefficients derived from the most thorough calibrations: and it will give these results directly in any standard units desired, regardless of the pressure and temperature of the gas flowing through the meter.

From a scientific standpoint it is interesting to note the remarkably close agreement of results that have been obtained in the tests by the several methods, which differ fundamentally in principle. The tests with natural gas at varying pressures also furnish an interesting check upon the generally-accepted statement that the specific heat of gases at constant pressure remains practically constant throughout the range of pressures commonly found in engineering.

The Rare Earths. C. R. BÖHM. (*Z. Angew. Chemie,* xxiv, 1203.)—Zirconia, which is now more easily obtained from the native Brazilian zirconia than from zircon, is utilized in pottery, enamels, arc lighting, and in Röntgen ray therapeutics, and probably has a great future. For incandescent gas-lighting it cannot displace thoria, as thorium nitrate gives a more coherent and resistant product. This is probably due to its power of forming a foam-like mass on heating, which can be increased by adding about 2 per cent. of sulphuric acid before evaporating the solution. The formation of a voluminous and finely divided ash serves as a ready technical test of the quality. Thorium nitrate is specially suitable for mantles made of cotton and ramie fibres; but it swells too readily for use with artificial silk; in this case ammonia or other alkali is added to the impregnating liquid, or the impregnated material is treated with hydrogen peroxide. Ceria is the most easily procured rare earth; it constitutes about 50 per cent. of the waste product from the thorium industry. It can be used for incandescent lighting. Prior to the introduction of the metallic filament lamps, considerable quantities of yttria from gadolinite and of zirconia from zircon were used in the manufacture of Nernst lamps.

Photographic Irradiation. C. E. K. MEES. (*Astrophys. Jour.,* xxxiii, p. 81.)—The diameter of the photographic image of a star or spectral line is known not to be the real diameter of the object, and as different systems for the measurement of these quantities have been used as criteria for photographic photometry, it becomes necessary to investigate their relation to each other. Hitherto the general conclusion has been that the square root of the diameter of a star image is proportional to the logarithm of the exposures. Laboratory experiments were made with an illuminated slit photographed from a distance of 3 metres by a lens of 15 cm. focus, so that the reduction on the plate was approximately 20 : 1. The slit was illuminated by a Nernst burner, and the diameter of the developed images read with an eye-piece micrometer, one division being equal to 0.0075 mm. The results confirmed the law usually accepted.

THE EXAMINATION AND PHYSIOLOGICAL ACTION OF PATHOGENIC MINE ATMOSPHERES, WITH CONSIDERATIONS GOVERNING THE USE OF BREATHING APPARATUS.

BY

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THE atmosphere of a mine, and its relation to those workers whose lives it must support, is a subject of engrossing interest. While much space has been devoted, in the past, to the general topic of ventilation, it is but recently that a closer view has been taken of the subject, and a more minute discussion of the various integral constituents of the mine atmosphere has been entered into. A reason for this change is not far to seek. The past decade has witnessed the introduction of so-called "rescue" or "breathing" apparatus. As the aim of all such apparatus is to permit the wearer to penetrate an atmosphere which, for some reason, is incapable of supporting life, it is only natural that a careful investigation should have been made into the changes which take place in a normal atmosphere, causing it to become toxic or irrespirable. As any device designed to support life, under these abnormal conditions, must supply the wearer with an atmosphere more or less independent of the exterior, it follows that a study of the amount of air required by the average man under various conditions of physical work should have become all-important.

In the course of this paper the writer will attempt to discuss only those atmospheres which are likely to be met with in mines. From time to time terms applied by mining men to various atmospheres or constituents of an atmosphere may be used.

It might, therefore, be well to define at once what these terms are intended to convey. "Black" or "choke damp"[1] is the residual gas left after the partial or complete removal of the oxygen from the air. It is seldom found in a pure state, generally being mixed with proportions of normal air. In the pure state it may

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[1] Investigations on the Composition, Occurrence, and Properties of Black Damp, Haldane and Atkinson, *Trans. Inst. Min. Eng.*, vol. 8, p. 549.

TABLE I.

COMPOSITION OF BLACK DAMP.

	O	N	CO_2	CH_4	Air	Black damp	Fire damp
1. Podmore Hall Coll'y stopping in No. 4 Pit.	1.45	82.56	10.64	5.35	6.94	87.71	5.35
2. Same, two months later.	0.72	80.78	11.03	7.47	3.44	89.09	7.47
3.	10.09	89.38	0.05	0.48	48.23	51.29	0.48
4.	5.08	91.81	2.92	0.19	24.30	75.51	0.19
5.	0.90	93.01	3.05	3.04	4.33	92.63	3.04
6.	trace	94.79	2.68	2.53	trace	97.47	2.53

Analyses 1 and 2 were taken from "Black Damp," by Haldane and Atkinson, *Trans. Inst. Min. Eng.*, vol. 8, p. 551.

Analyses 3, 4, 5, and 6 are from the author's experience and are representative of black damp from anthracite mines.

TABLE II.

COMPOSITION OF FIRE DAMP.

	O	C_nH_{2n}	N	CO_2	CH_4	Air	Black damp	Fire damp
1. Fire damp from pipe inserted in coal, Minnie Pit, Podmore Hall. . . .	0.1		9.4	4.1	86.4	0.5	13.1	86.4
2. Garswood Hall.			2.24	.86	84.16	12.64		84.16
3. Garswood Hall.			2.27	.86	88.86	8.01		88.86
4. Accumulation of gas at roof.		0.09		1.45	50.67	29.33	19.91	50.67

Analysis 1 is taken from "Black Damp," Haldane and Atkinson, *Trans. Inst. Min. Eng.*, vol. 8, p. 554.

Analyses 2 and 3 are taken from "Elementary Chemistry for Coal Mining Students," O'Shea, p. 119.

Analysis 4 is taken from *Bull.* 383, *U. S. Geol. Sur.*, p. 31.

be roughly said to consist of from 85 per cent. to 99 per cent. of nitrogen, and from 1 per cent. to 15 per cent. of carbon dioxide. "White damp" is the name given by miners to carbon monoxide. "After damp"[2] is a mixture of air, black damp, white damp, and carbon dioxide. It results from the explosion of mixtures of fire damp or coal dust and air, and when fresh is sometimes deeply colored by smoke or soot. A gas of similar composition results from underground fires. "Fire damp"[3 4] is a combustible gas composed principally of methane, but also containing small proportions of hydrogen, ethane and higher hydrocarbons. It always occurs mixed with varying amounts of oxygen, nitrogen, and carbon dioxide. Analyses are given in Tables I and II of airs containing these bodies.

The first step in a systematic study of mine atmospheres should be the collection of reliable analytical data. It is important to know exactly the proportion of oxygen, nitrogen, carbon dioxide, carbon monoxide, hydrocarbon gases calculated as methane, and, in rare instances, hydrogen sulphide and sulphur dioxide.

The practical value of such information is hardly as yet appreciated by mine operators in general. It might, therefore, be well to mention, in passing, a few applications of these data.

By a careful study of well-chosen analyses of air from different entries and returns, throughout a mine, it is possible to discover regions receiving ventilation in excess of their needs. When this excess air is diverted to regions more in need of ventilation an insufficient air supply may sometimes be made adequate.

When an attempt is being made to extinguish a mine fire by cutting off its air supply, it is possible by the analysis of samples taken through bore holes or pipes in stoppings to obtain very accurate information as to the progress of the work. It is also possible, by this means, to detect at once any access of fresh air.

When an atmosphere of questionable purity is to be entered, for the purpose of doing rescue work or fighting mine fires, the advantage of applying tests for its respirability is self-evident.

Thus a party equipped with breathing apparatus might precede their unprotected companions and accurately ascertain just how far it was safe for the latter to proceed. While men were at

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[2 3] Notes on Explosive Mine Gases and Dusts, Chamberlin, *U. S. Geol. Survey, Bull.* 383.

[4] Fire Damp: Its Composition, Detection, and Estimation, Gray, *Trans. Inst. Min. Eng.*, vol. 30, p. 286.

work without breathing apparatus, in a dangerous environment, one of their number could, by making frequent tests, determine any increasing toxicity of the air and thus warn his companions in time for a safe retreat.

Under certain conditions the so-called " safety lamp " ceases to yield reliable indications, and more precise methods must be looked to. For example, in testing a body of black damp, containing below 16 per cent. of oxygen and 6 per cent. to 7 per cent. of methane, the lamp will first show a pronounced cap. As the lamp is approached more closely to this body of gas, the cap will increase in size, and may eventually entirely fill the gauze. On entering the body of damp, however, the flame will be extinguished. As this behavior is supposedly characteristic of a body of pure fire damp, the most experienced miner may be led to a false diagnosis, the true nature of the gas body only being discoverable by chemical analysis.

The actual analysis of a sample of mine air is by no means as simple a matter as might at first appear. To begin with, the limit of error permissible in such work is of an entirely different order from that in the analysis of fuel or flue gases. The constituents to be determined, with the exception of oxygen and nitrogen, are for the most part present in extremely small quantities, while the presence or absence of one or two of these may be of vital importance. Thus the classic methods based on the selective absorption in rotation of the various components of a gaseous mixture, the quantity of each being estimated by the decrease in volume of the gas, are unsatisfactory, except in the determination of oxygen. By this procedure such a small volume of sample is operated upon, and the substances to be determined are present in such small quantities, that the error is unpermissibly great. It is true that Haldane[5] has devised a very ingenious apparatus working on the above principle. It has been the author's experience, however, that the apparatus is so complicated and its manipulation so cumbersome that other methods are preferable.

With these points in view, the writer has, after considerable experimentation, selected a number of methods from the literature, and has found them to give most satisfactory results. A detailed description of these methods would lie without the scope of this paper. It will suffice, therefore, briefly to touch upon their salient points.

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[5] The Investigation of Mine Air, Foster and Haldane, p. 97.

The gas samples are collected in copper cylinders of about 3 litres capacity, with conical ends, each end carrying an accurately ground tubulated brass stop cock. When a sample is to be taken, a cylinder is filled with clear water, and carried to the desired spot. On opening the cocks, the can will be filled with air as the water recedes. As soon as the can is free of water the cocks should be closed. If the sample is to be taken from a pipe or bore hole, a rubber tube of small bore, previously filled with water, is slipped over one of the cocks. The tube may then be thrust or lowered into the pipe or bore hole to the desired point. While holding the cylinder in a vertical position, with the cock bearing the rubber tube uppermost, the cocks are opened, when the desired sample will be drawn into the cylinder. It is important in using these cans to allow all water to drain out, when taking the sample, and to make the analysis as soon as practicable.

Carbon dioxide is determined by the method of Pettenkofer[6] or Hesse. This method has many variations. The following, however, has been found to give thorough satisfaction: A heavy litre or litre-and-a-half Erlenmeyer flask, the volume of which has been previously determined, is filled with water at room temperature, and then filled, by displacement, with the air to be analyzed. The flask is closed with a well-fitting two-hole rubber stopper, the apertures of which are closed by glass rods. A known excess of a clear solution containing 15 gm. of barium hydroxide and 1 gm. of barium chloride per litre is then run from an automatic pipette through one of the holes of the stopper. After closing, the flask is allowed to stand, with frequent shaking, for at least a half hour. At the end of this period the rods are withdrawn, the barium hydrate solution is tinted with phenolphthalein, and cautiously titrated with gas-normal oxalic acid. This solution contains 5.629 gm. of crystallized oxalic acid per litre, 1 c.c. being equivalent to 1 c.c. of carbon dioxide, measured at 0° C. and 760 mm. pressure. While the carbon dioxide is being absorbed, another portion of the barium hydroxide solution is titrated with the oxalic acid. From this determination the ratio of oxalic acid to barium hydroxide is found. The volume of carbon dioxide in the sample operated upon is thus readily obtained by subtracting from the volume of oxalic acid, equivalent to the quantity of barium hydroxide originally taken, the volume of oxalic acid required after the absorption of the carbon dioxide. In calculating the percentage of carbon dioxide, note must be made of the thermometer and barometer readings when the flask is filled with air for analysis. From these values the volume of the air contained is reduced to normal conditions, first deducting the volume of the barium hydroxide added. Great care should be taken in adding the barium hydroxide, as well as in the subsequent titration, that there be as little opportunity as possible for the air in the flask to mix with the outside air. Most commercial samples of barium hydroxide contain some alkali metal hydroxide. In such a case alkali metal oxalate may be formed, when at the close of the titration the following reaction will occur:

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[6] A Systematic Handbook of Volumetric Analysis, Sutton, 10th ed., p. 102.

Methods of Gas Analysis, Hempel, 3d German ed., p. 346.

Handbook of Technical Gas Analysis, Winkler and Lunge, 2d English ed., p. 103.

The Investigation of Mine Air, Foster and Haldane, p. 44.

Quantitative Chemical Analysis, Olsen, 4th ed., p. 301.

Quantitative Chemical Analysis, Clowes and Coleman, 8th ed., p. 476.

A System of Instruction in Quantitative Chemical Analysis, Fresenius, 2d American ed., p. 776.

Analytical Chemistry, Treadwell, vol. 2, 2d ed., p. 551.

Technical Methods of Chemical Analysis, Lunge, p. 870.

$$Na_2C_2O_4 + BaCO_3 = BaC_2O_4 + Na_2CO_3$$[7]

Under these conditions the bleaching of the color of the phenolphthalein is not permanent, the color returning after repeated addition of acid, and thus shrouding the end point in uncertainty. By the addition of barium chloride the alkali metal hydroxide is converted to chloride and rendered innocuous, the end point once more becoming sharp. As the dilute solution of oxalic acid used is far from stable, a fresh solution should be frequently prepared. The barium hydroxide solution should be protected from the carbon dioxide of the air by the usual methods. The accuracy of this method has been demonstrated by the exhaustive researches of Letts and Blake.[8] Its precision will become apparent when it is considered that, granting the burette may be read to 0.05 c.c. and that 1000 c.c. of air are operated upon, the error in reading should not exceed 0.005 per cent. of carbon dioxide. There is, of course, an ever-present error due to the solution of carbon dioxide in the water when filling the sample can and transferring the air to the flask. This error, however, is small with careful work. Hydrogen sulphide and sulphur dioxide, if present, must be corrected for.

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[7] Quantitative Chemical Analysis, Olsen, 4th ed., p. 303.

The determination of methane is best carried out on the residual gas from the carbon dioxide determination, although, if desired, a fresh portion may be taken. Two methods recommend themselves for this purpose. In the first,[9] or Winkler's method, the methane is slowly oxidized by means of a heated platinum helix and atmospheric oxygen. In the second it is oxidized by contact with heated copper oxide, independent of atmospheric oxygen.

If the first method is to be pursued the original stopper is replaced by one carrying two brass rods, the transfer being made while the flask is held inverted with its mouth just under water. These rods extend within about 5 cm. of the bottom of the flask, and are joined at their inner extremities by a piece of platinum wire 0.35 mm. in diameter and 7 cm. long, bent in the form of a helix. The outer extremities are connected with a source of electricity. The flask is inverted and held in this position entirely submerged in a bath of cold water. A current of electricity is now passed through the apparatus sufficient to raise the platinum wire to a dull red heat. It is gradually increased during a half hour to about 9 amperes, or sufficient to bring the platinum to incipient whiteness. At the expiration of this period the current is broken, the flask removed from the water, the stopper used in the carbon dioxide method substituted for the one bearing the brass rods, and the carbon dioxide formed by the combustion of the methane is determined as previously described. In this case, however, each c.c. of oxalic acid consumed is equivalent to 1 c.c. of methane, measured under normal conditions. This method has many drawbacks. Heat enough is often generated to develop pressure sufficient to cause leakage of gas around the stopper, to blow the stopper out or to burst the flask. The flask may be subjected to such unequal heating as to cause it to crack spontaneously. It is always possible that traces of methane may escape oxidation. Moreover, if the percentage of methane be high, as in the analysis of fire damp, or if the percentage of oxygen be low, as in the analysis of black damp, it is necessary to mix the gas to be analyzed with either pure air or oxygen, an operation which is time-consuming, troublesome, and apt to engender grave errors. Should the percentage of methane fall within explosive limits, the method is entirely inapplicable, as even with dilution there is danger of an explosion. Under ideal conditions the accuracy obtainable by this method is of the same order as that in the carbon dioxide determination.

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[8] *Proc. Chem. Soc.*, 1896, 192.

[9] Examination of Mine Air, Foster and Haldane, p. 52.
Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 156.

After a lengthy trial of the first method, the writer has adopted the second, or that of Fresenius modified by Winkler.[10] Either the flask containing the air from the carbon dioxide determination, or one filled with a fresh sample, is arranged so that the contained gas may be displaced by water. The air is led first through a soda lime tube, a calcium chloride tube, and then a combustion tube. This combustion tube is of heavy copper, 45 cm. long and 2 cm. in diameter. It is partly filled with coarse copper oxide, is heated to redness by four Bunsen burners, and is provided, at either end, with an annular copper jacket, about 5 cm. long, through which cold water is circulated. These water jackets cool the perforated rubber stoppers through which the air is led, as well as the copper gauze with which each end of the tube is packed. This gauze serves a double purpose; it holds the copper oxide in place, and, should the gas to be analyzed be explosive, acts as the gauze in a Davy safety lamp, eliminating danger from this source. The air, on leaving the combustion tube, is passed through two 200 c.c. Erlenmeyer flasks. These flasks contain a known volume of barium hydroxide solution, of the same strength as used in the determination of carbon dioxide, and a few drops of phenolphthalein. After the sample of air has passed through the combustion train, an operation requiring about 35 minutes, the flask in which it was originally contained is removed, and air from without the building is aspirated through the apparatus for about 25 minutes. The two absorption flasks are removed, their contents combined and titrated with oxalic acid as in the determination of carbon dioxide. This method will give accurate results irrespective of the proportion of oxygen or methane in the original sample. The copper oxide in the tube is regenerated by the passage of air after the gas sample, thus leaving the tube in good condition for the next determination. It is important that the air samples should not be passed through the apparatus too rapidly, and that a notable excess of barium hydroxide be maintained in the absorption flask. The barium hydroxide is therefore tinted with phenolphthalein to give warning of its depletion.

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[10] Handbook of Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 164.

It might be well to review some considerations governing these methods. In correcting the volume of the sample in the flask, if the residual air from the carbon dioxide determination be used, both the volume of barium hydroxide and oxalic acid used in the carbon dioxide determination must be deducted before reducing the air volume to normal conditions. In the first method, when calculating the volume of air in the flask an additional deduction must be made for barium hydroxide added and for the volume of the brass rod electrodes. Of course, in the second method this correction does not apply. In determining methane by the first method, on a sample of air from which carbon dioxide has not been removed, the percentage of carbon dioxide in the air must be deducted from the percentage of methane found. This correction is unnecesssary in the second method, as all carbon dioxide is removed by the soda lime tube. In both methods the percentage of carbon monoxide in the air must be deducted from the percentage of methane found, as one volume of carbon monoxide burns to one volume of carbon dioxide as does one volume of methane. In the first method hydrogen sulphide and sulphur dioxide, if present, must also be corrected for.

The accurate determination of even traces of carbon monoxide is of paramount importance. This fact, coupled with the chemical properties of the gas itself, renders recourse to special methods necessary. The well-known unreliability of the methods based on its absorption by solutions containing cuprous chloride forbids even the thought of their application here. Haldane[11] has endeavored to apply the well-known gas volumetric method based upon the changes of volume occurring when this gas is burned and when the resultant carbon dioxide is absorbed. As has been noted, however, such methods, through inherent weakness, would seem to fall far short of giving the desired accuracy. There is, moreover, nothing positive about these methods. For this reason the so-called blood-test[12] has found considerable favor. In this test advantage is taken of the pink color given to dilute solutions of blood by carbon monoxide hemoglobin. This test, when properly performed by an experienced operator, gives qualitative indications of undoubted value. The personal equation, however, plays too prominent a rôle to permit of its quantitative application, though much has been written to the contrary. If the blood solution containing carbon monoxide be examined spectroscopically[13] the indications are said to become quantitative, however, this method having a wide application in the field of forensic chemistry. Apropos of the qualitative value of the blood-test, another well-known qualitative test might be mentioned. This consists in passing the air to be examined through a solution of sodium cuprous chloride, diluting somewhat and adding a few drops of sodium palladious chloride,[14] when, if carbon monoxide be present, a black precipitate should be formed. This test may be varied by passing the air through a small quantity of water containing strips of filter paper moistened with palladious chloride,[15] the paper blackening in the presence of this gas. A quantitative variation based upon these reactions has been brought forward by Potain[16] and Drouin. The detection of carbon monoxide by any of these alternatives is, however, unsatisfactory, as too great a volume of air is required for convenience, and there are many interfering substances. A method has been devised by Spitta,[17] in which the carbon dioxide produced by the combustion of carbon monoxide by silver electrodes, coated with palladium and heated to 150° to 160° C., is determined by Pettenkofer's method. This method is said to be applicable in presence of hydrocarbons, and to possess considerable accuracy.

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[11] The Investigation of Mine Air, Foster and Haldane, p. 98.

[12] *Loc. cit.*, p. 147.
Trans. Inst. Min. Eng., vol. 11, p. 502.
Trans. Inst. Min. Eng., vol. 38, p. 267, Haldane and Douglas.
Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 892.

[13] A Text-book of Legal Medicine and Toxicology, Peterson and Haines, vol. 2, p. 658.
Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 890.

[14] Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 74.

[15] Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 889.

[16] *Comptes rend.*, 1898, vol. 126, p. 938.

Probably the methods best adapted to the determination of carbon monoxide in mine air are based upon its oxidation by iodine pentoxide, as pointed out by de la Harte and Reverdine.[18] This reaction proceeds as follows: $5CO + I_2O_5 = 5CO_2 + I_2$, and is quantitative at from 150° to 160° C. If this latter temperature be not exceeded, methane and hydrogen have no action on the reagent, though hydrocarbons of the ethylene and acetylene series are attacked. As the latter gases occur but rarely in appreciable proportions in mine atmospheres, their action may generally be neglected. Hydrogen sulphide and sulphur dioxide might also interfere, but may be readily removed. Many different applications of this method have been brought forward. Gautier [19] absorbs the carbon dioxide formed, and measures its volume after liberation by acid. The same author [20] bases a gravimetric method upon the absorption of the iodine by spongy copper. Nicloux,[21] working at the same time as Gautier, though independent of him, has published a procedure in which the amount of iodine evolved is determined colorimetrically after solution in chloroform. Fillinger [22] has described an apparatus brought forward by Molterski and Norwicki, in which, after removal of the free iodine by metallic silver, the carbon dioxide generated is determined by Pettenkofer's method. A method in which the liberated iodine is absorbed by a solution of potassium iodide, and subsequently titrated with N/1000 sodium thiosulphate, has been described in an excellent paper by Kinnicutt[23] and Sanford. In this paper the experimental error of the method was shown to be from ± 0.001 per cent. to 0.0027 per cent., when the carbon monoxide present in the gas varied from 0.023 per cent. to 0.041 per cent., the error, of course, depending on the proportion of carbon monoxide. Their procedure, with slight modifications by the author, may be thus described:

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[17] *Arch. Hygiene,* 46, 284.
Jour. Soc. Chem. Ind., 1903, 22, p. 652.

[18] *Chem. Zeit.,* 1888, vol. 12, p. 1726.

[19] *Comptes rend.,* 1898, vol. 126, p. 931.

[20] *Comptes rend.,* 1898, vol. 126, p. 1299.

[21] *Comptes rend.,* 1898, vol. 126, p. 746.

[22] *Osterreichische zeitschrift für Berg und Huttenwesen,* 1903, vol. 51, pp. 216, 217.

One of the copper sample cans containing the air to be analyzed is placed in a vertical position, and so arranged that water, at room temperature, may be admitted through the bottom tap. The air thus displaced passes through the upper tap to a U tube, the first leg of which contains calcium chloride, the other soda lime. It then passes through a small U tube, containing about 25 gm. of iodine pentoxide, mixed with sufficient glass wool or asbestos to render it porous. From this tube the air passes to a Bowen absorption tube containing about 5 c.c. of 10 per cent. potassium iodide. The tube containing the iodine pentoxide is surrounded by a sand bath, the temperature of which is held between 150° and 160° C. The sample of mine air is passed through the apparatus at a rate of about 1 litre per hour. One litre of air is the quantity usually used, though more may be taken if desired. After the requisite quantity of air has been passed through the apparatus the lower cock of the sample can is closed, and when the bubbles cease to pass through the absorption tube the upper cock is closed and the can is removed. An aspirator is attached to the absorption tube and a slow current of air from outside the building is drawn through the apparatus for about one-half hour. The absorption tube is then removed, its contents rinsed out with distilled water, and titrated with N/1000 sodium thiosulphate, with the addition of a little starch liquor. Each c.c. of the thiosulphate required is equivalent to 0.056 c.c. of carbon monoxide, measured under normal conditions. The quantity of air which has been passed through the apparatus may be determined by measuring the quantity of water in the sample can, or by noting the increase in weight of the can. The volume of air thus determined must be reduced to normal conditions.

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[23] *Jour. Amer. Chem. Soc.*, 1900, vol. 22, p. 14.

In their paper Kinnicutt and Sanford purify the air before bringing it into contact with the iodine pentoxide, by passing it first through concentrated sulphuric acid and then over solid potassium hydroxide. This procedure is said to eliminate interfering unsaturated hydrocarbons. As the presence of such in mine air is problematic, as the sulphuric acid, owing to its contamination by organic matter, is apt to generate sulphur dioxide, and as the back pressure of the column of acid would have to be allowed for in computing the volume of air used in analysis, the simpler combination described has been substituted, the function of which is to remove hydrogen sulphide, sulphur dioxide, and water vapor. Should the presence of ethylenes or acetylenes be suspected, the former method may be desirable. These writers, in their work, used an oil bath. It has been found, however, that such baths are not applicable here, as the oil creeps and on coming in contact with the iodine pentoxide liberates iodine. It is important to keep the volume of the purifying tube as small as possible, as less air is thus required to sweep the apparatus clean. It is not practicable to use the air of the laboratory for this sweeping out, as it generally contains sufficient carbon monoxide from leakage of illuminating gas to vitiate the results. The apparatus throughout should be glass-stoppered, and all connections should be of glass tubing, held firmly with glass against glass, so that there is as little contact as possible with rubber. The weak standard sodium thiosulphate is far from stable. For this reason it is best to prepare a N/10 solution and to dilute 10 c.c. of this to 1 litre as required.

Of the many methods proposed for the estimation of oxygen, two have stood the test of long usage. In the first the oxygen is absorbed by a solution of pyrogallol[24] in strong potassium hydroxide. In the second the slow combustion of phosphorus[25] at room temperature is utilized. While these methods are so well known that their description is unnecessary, a few remarks concerning the applicability of each might be acceptable. The pyrogallate method gives results of unquestionable accuracy when properly carried out. The solution, however, due to its causticity, is unpleasant to handle. It, moreover, deteriorates rapidly, and there is therefore some uncertainty as to the efficiency of a previously-used solution. The advantage of the method lies in the fact that other gases do not interfere with the absorption of oxygen.

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[24] Handbook of Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 70.
The Investigation of Mine Air, Foster and Haldane, p. 32.
Methods of Gas Analysis, Hempel, 3d ed., p. 149.

[25] Handbook of Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 68
The Investigation of Mine Air, Foster and Haldane, pp. 7, 31.
Methods of Gas Analysis, Hempel, 3d ed., p. 155.

In the phosphorus method the pipette containing the reagent must have a temperature of at least 18° or 20° C., the absorption being very slow below this point, almost ceasing, indeed, at 7°. In the presence of certain gases the action of the phosphorus is prevented. Brunck[26] states that the absorption is not rendered slower or less complete by the disturbing gases, but that if white fumes are evolved on bringing the air to be analyzed in contact with phosphorus the reaction will be quantitative. The writer has not met with a sample of mine air to which the phosphorus method was inapplicable. Should difficulties be encountered, however, the former method will be found satisfactory. The advantages of the latter method are its cleanliness, rapidity, and accuracy. An apparatus when once set up can be used for years without renewal of the reagent. The Lindemann[27]-Winkler apparatus will be found convenient, as it is self-contained, requires little manipulation, and may be carried into the mine when desired. With this apparatus results should be obtained differing by not more than 0.1 per cent.

Nitrogen is always determined by difference.

Hydrogen sulphide and sulphur dioxide are generally detected by their odor. It is better, however, in the case of hydrogen sulphide to use strips of alkaline lead acetate paper, as the olfactory organs are apt to become untrustworthy. Quantitatively it may be determined by the depth of color produced when a known volume of air is passed over lead acetate paper,[28] or by passing the air through a solution of iodine and volumetrically determining the iodine consumed by black titration with sodium thiosulphate.[29] Sulphur dioxide may be determined iodimetrically[30] as just mentioned, or may be weighed as barium sulphate[31] after oxidation with hydrogen peroxide.

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[26] The Investigation of Mine Air, Foster and Haldane, p. 8.

[27] Technical Gas Analysis, Winkler and Lunge, 2d ed., p. 92.
The Investigation of Mine Air, Foster and Haldane, p. 39.

[28] Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 888.

The results of an analysis of mine air for ready interpretation are stated in two forms. The values found for oxygen, nitrogen, carbon dioxide, carbon monoxide, and methane comprise the first. The percentage of normal air is then calculated by multiplying the percentage of oxygen found by 100, dividing by 20.93. This value is termed "air." Methane is reported as "fire damp" and carbon monoxide as "white damp." The percentage of carbon dioxide less 0.03 per cent. is termed "excess carbon dioxide." 100 per cent. less the sum of the percentage of "air," "excess carbon dioxide," carbon monoxide, and methane gives the "excess nitrogen." It is often convenient to term the combined values for "excess carbon dioxide" and "excess nitrogen"—"black damp." The second statement of results will therefore contain the figures for "air," "fire damp," "white damp," and "black damp."

The intelligent interpretation of an analysis of mine air requires a knowledge of the sources, physical and chemical characteristics, and physiological action of the various gases determined. As this information is scattered through a great volume of literature, an effort will be made to give a brief *résumé* of the more important data.

In the past it has been customary to divide atmospheres into two classes: extinctive and non-extinctive. This classification, however, is purely arbitrary, being based upon the effect of the air upon the miner's lamp or candle. It is well known that, as the percentage of oxygen in an atmosphere falls, a point is reached at which the ordinary wick-fed flame is extinguished. If, however, the flame is gas-fed and burns from a jet, the point at which it will be extinguished is variable, depending entirely upon the nature of the gas burning. Professor Clowes[32] has published a classic work on this subject, from which the following table has been taken.

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[29] Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 888.

[30] Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 886.

[31] Technical Methods of Chemical Analysis, Lunge, vol. 1, p. 886.

[32] *Trans. Inst. Min. Eng.*, vol. 9, p. 376.
Proc. Royal Soc., vol. 56, 1894, p. 2.
Trans. Inst. Min. Eng., vol. 7, p. 419.

TABLE III.

COMPOSITION OF THE RESIDUAL ATMOSPHERES AND OF THE ARTIFICIAL ATMOSPHERES WHICH EXTINGUISH FLAMES, AND OF AIR EXPIRED FROM THE LUNGS.

Combustible substances burnt	Percentage composition of the residual atmospheres in which the flame was extinguished			Proportions per cent. of O_2 and N_2 in which flame is extinguished when introduced	
	O_2	N_2	CO_2	O_2	N_2
I.					
Alcohol, absolute..........	14.9	80.7	4.35	16.6	83.4
Alcohol, methylated.......	15.6	80.25	4.14	17.2	82.8
Paraffin lamp oil..........	16.6	80.4	3.0	16.2	83.8
Colza and Paraffin.........	16.4	80.5	3.1	16.4	83.6
Candle....................	15.7	81.1	3.2	16.4	83.6
II.					
Hydrogen................	5.5	94.5	....	6.3	93.7
Carbon Monoxide..........	13.35	74.4	12.25	15.1	84.9
Methane..................	15.6	82.1	2.3	17.4	82.6
Ethylene (failed)..........	....	....	....	13.2	86.8
Coal Gas..................	11.35	83.75	4.9	11.3	88.7
III.					
Expired Air (average)......	16.15	79.9	3.95	....	....
Fresh Air (average)........	20.9	79.06	0.04	....	....

Though much stress has been laid upon the extinction of a lamp flame by a vitiated atmosphere, the principal importance of the phenomenon lies in the warning it gives to the miner that there is danger of the air becoming so vitiated as to no longer support life. If we go further into the matter, however, this property becomes of paramount importance; instead of being a source of danger, it becomes one of the most efficient weapons at our disposal in fighting mine fires. In this connection it might be well to note a popular misconception of the *modus operandi* of the extinctive atmosphere. For some reason it is generally supposed that such an atmosphere has a quenching action similar to water upon a fire. This, of course, is not the case. As the percentage of oxygen in the air feeding a fire drops, the rate of combustion decreases, and with it the quantity of heat developed during a given time. Thus when a certain percentage of oxygen is reached the rate of evolution of heat becomes less than the rate of loss of heat, the temperature of the burning body falling until a point is reached at which re-ignition cannot take place. At this point the fire is said to be extinguished. It will thus be seen that the time required to smother a fire by cutting off its air supply is as much dependent upon the mass of the burning material and the nature of the conducting material surrounding it as upon the composition of the air.

As at present there seems no satisfactory classification of various atmospheres considered as a whole, and as these atmospheres generally differ only in the proportion of their constituents, the sources, properties, and physiological actions of these constituents will be briefly noted.

The general properties of oxygen are too well known to be given space here, though a few words may be devoted to its action on man. The mechanics of the absorption of oxygen by the hemoglobin, and its distribution through the tissues by this medium, is well understood. Normally the human organism is supposed to operate on air containing about 21 per cent. of oxygen. It is remarkable, however, how adaptable this organism is to divergences from this percentage. For some reason general credence has been given to the statement that if air rich in oxygen be breathed for any length of time an exhilaration will be experienced which, if the inhalation be continued, will verge into a delirium resembling alcoholic intoxication. Professor Leonard Hill,[33] quoting the work of Bornstein, Lorain Smith, J. J. R. Macleod, and himself, states that concentrations of oxygen up to 100 per cent. can be borne for long periods without ill effect. The writer has personally administered fairly pure oxygen to men many hundreds of times, and has in no case observed any disturbance of function in the subject.

The question of the effect of an insufficiency of oxygen has been ably treated by Haldane[34] and Lorain Smith. These phenomena, however, are generally considered under the action of black damp and fire damp, but as both these gases are inert their effects are largely due to the lack of oxygen which they displace. In mines a deficiency of oxygen may arise, either from underground fires or, in the absence of fire, from the direct combination of the atmospheric oxygen with the constituents of the coal. Haldane[35] states that "a person not exerting himself will as a rule not notice anything unusual until the oxygen percentage has fallen to 10 per cent. The breathing then usually begins to become deeper and more frequent, the pulse more frequent, and the face somewhat dusky. At 7 per cent. there is usually distinct panting, accompanied by palpitations, and the face becomes of a leaden-blue color. At the same time the mind becomes confused and the senses dulled, although the person breathing the air may be quite unaware of the fact. Muscular power is also greatly impaired. At a slightly lower percentage there is complete loss of consciousness." Virtually the same statements appear so frequently in the literature that they may be considered to be authoritative. The writer has had the opportunity of witnessing several cases of asphyxia induced by exposure to black damp and fire damp. He has also discussed the matter with many experienced miners who have undergone the same unpleasant ordeal, and there seems to be no doubt that, in addition to the symptoms described above, there is considerable nausea and severe headache, coupled with great lassitude. It must be borne in mind, in discussing the physiological action of a mine atmosphere, that the effect noticed is seldom, if ever, traceable to a single gas, but is the resultant of the effects caused by its various components.

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[33] *Trans. Inst. Min. Eng.*, vol. 35, p. 25.
Proc. Royal Sanitary Inst., 1911.

[34] *Journal of Pathology and Bacteriology*, vol. 1, p. 168.

Carbon dioxide is a constant constituent of mine atmospheres. Its presence is traceable to various sources. The most important of these is the coal itself. At ordinary temperatures atmospheric oxygen slowly oxidizes the coal, producing carbon dioxide as one of the products of this oxidation. The respiration of men and animals and the combustion of miners' lamps or candles are less important sources of this gas.

Much stress has been laid in the literature upon the toxicity of carbon dioxide. Though under certain conditions the gas possesses undoubtedly toxic properties, it would seem that in the vast majority of cases the damage done by insufficiency of oxygen has been laid at the door of carbon dioxide. Indeed, there seems to be considerable confusion on this point in the minds of many writers. We read of men being overcome by carbon dioxide when descending into wells, old shafts, or ill-ventilated parts of a mine. In truth, it is difficult to conceive of an atmosphere, barring one synthetically prepared, in which there could be a lethal percentage of carbon dioxide and at the same time sufficient oxygen to support life. It is more reasonable to believe that a primary insufficiency of oxygen in these cases is made more deadly by the carbon dioxide associated with it.

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[35] Investigations of Mine Air, Foster and Haldane, p. 142.

In discussing its physiological action, reference must again be made to the classic work of Dr. Haldane, who has described with clarity and elegance the mechanics of the metabolism of this gas. Indeed, the matter has been so ably treated that the writer can do not better than to quote from this authority:[36]

"Mr. Priestley and the writer have shown that at ordinary atmospheric pressure the breathing always regulates itself in such a way as to keep the percentage of carbonic acid in the air cells (alveoli) of the lungs constant. Each individual has his own exact percentage; but on an average there is about 5.6 per cent. of carbonic acid in the aveolar air of man. The regulation is almost astoundingly exact for each person.

"If air containing carbonic acid is breathed, the respirations become deeper, in such a way that the alveolar carbonic acid percentage still remains practically the same, if possible. If, for instance, there is 2 per cent. of carbonic acid in the air, the breathing will need to be about 50 per cent. deeper than before. This difference would not be noticed by the person, but is easily detected by measurement. If there is 5 per cent. of carbonic acid in the air, it requires much panting to keep the alveolar carbonic acid percentage nearly constant; if there is 6 or 7 per cent., it is, of course, quite impossible to maintain a normal alveolar carbonic acid percentage, and great distress is produced, as the blood becomes abnormally charged with carbonic acid, to which the body is exquisitely sensitive. If breathing of ordinary pure air is forced, so that the carbonic acid percentage in the alveolar air is abnormally reduced, natural breathing is afterwards suspended for a short time, the condition known as apnœa being produced. It is carbonic acid, and carbonic acid alone, which regulates our breathing under normal conditions. The supposed ill effects of a small percentage of carbonic acid in the inspired air are wholly imaginary, as a very slight increase in the depth of breathing at once compensates for the extra carbonic acid. Provided that this compensatory effort is practically inappreciable, we may wholly disregard it. To any moderate variations in the oxygen percentage of the inspired or alveolar air there is no corresponding physiological response.

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[36] *Trans. Inst. Min. Eng.*, vol. 35, p. 303.

"The writer and Mr. Priestley found that when the atmospheric pressure was varied it was the partial pressure, and not the percentage of carbonic acid, that remained constant in the alveolar air. The percentage varies inversely as the absolute atmospheric pressure, and was thus found to be lower at the bottom than at the top of a mine shaft and lower in compressed air in exact inverse proportion to the increase of absolute pressure. To take extreme values, Dr. Boycott and the author have found 15 per cent. of carbonic acid in the alveolar air when the atmospheric pressure was diminished to nearly a third, some oxygen being, however, added to the air in order to prevent asphyxia from the low partial pressure of oxygen; on the other hand, Drs. Leonard Hill and Greenwood found only 0.9 per cent. of carbonic acid at an absolute pressure of 6 atmospheres. The partial pressure of the carbonic acid was, however, the same in each case."

Thirkell[37] has tabulated the action of carbon dioxide as follows:

TABLE IV.

Percentage of carbon dioxide present.	Effects on man.	Effects on lights.
3.5	Breathing deeper.	Still burns.
6.0	Marked panting.	Still burns.
10.0	Severe distress.	Still burns.
15.0	Partial loss of consciousness.	Extinguished.
25.0	Final death.	Extinguished.

He fails to state, however, whether the percentages of carbon dioxide noted were added to an atmosphere of normal composition or were produced by combustion. It is evident, from an inspection of the table, that the former hypothesis is the more likely. The consideration of these data may be aided by the statement that the author has analyzed many samples of anthracite mine air, containing from a trace to 10 per cent. of oxygen, in which the carbon dioxide never exceeded 5 per cent.

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[37] *Trans. Inst. Min. Eng.*, vol. 8, p. 392.

The presence of carbon monoxide in mine air may be traced to several sources. As it is a product of the incomplete combustion of carbonaceous substances, it is formed by explosions of coal dust or fire damp, by underground fires, and by the detonation of most explosives. It is well known that carbon monoxide is produced when air at ordinary temperature acts upon bituminous coal. It has remained, however, for Mahler[38] and Denet to prove the presence of this gas in mine air from such a source. These writers have found as much as 0.004 per cent. of carbon monoxide in the air of well-ventilated mines. The statement may be found in the literature that this gas is also produced by the decomposition of organic matter other than coal in the mine. As the presence of carbon monoxide has been considered indicative of mine fires, its presence from other causes must be given due weight before forming a definite opinion as to the existence of a fire.

Its principal claim on our attention, however, lies in its physiological action. As this gas is odorless and non-irritant, it may be breathed in considerable quantity without the subject being aware of the fact, the first warning being given by grave functional derangement. Briefly, the mechanics of its action may be thus described: Carbon monoxide, having an affinity for hemoglobin about 200 times greater than that of oxygen, readily replaces the latter in the blood when breathed. As the blood becomes saturated with carbon monoxide its oxygen capacity becomes correspondingly diminished, until it can no longer supply sufficient oxygen to fulfil the requirements of the organism. In addition to this, the gas is said to cause degeneration of the cells of the organism, and thus serious nervous disorders are brought about. Haldane[39] and Douglass state that physical disablement is produced in man when about 50 per cent. of the blood is saturated with carbon monoxide, death occurring when this figure increases to 80 per cent.

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[38] *Comptes rend.*, 1910, 151, 645–647.

[39] *Trans. Inst. Min. Eng.*, vol. 38, p. 271.

Owing to its great affinity for carbon monoxide, the blood may become saturated to a dangerous extent when this gas is present even in minute quantities. It is difficult to give fixed points at which an atmosphere containing carbon monoxide will produce given effects. It has been stated, however, that quantities under 0.02 per cent. have no appreciable action on man, while the lethal percentage has been fixed at 0.5 per cent. Herman[40] has tabulated the action of carbon monoxide as follows:

TABLE V.

Percentage present in air.	Effects on man.
0.05	After half an hour or more, giddiness on exertion.
0.1	After half an hour or more, inability to walk.
0.2	After half an hour or more, loss of consciousness and perhaps final death.
1.0	After a few minutes, loss of consciousness and final death.

When any given percentage of carbon monoxide is breathed, the blood tends to reach a degree of saturation at which the carbon monoxide and oxygen in the air are in equilibrium with the carbon monoxide in the blood. If we apply the law of Mass Action to this phenomenon, it will be readily seen that a change in the proportion of oxygen will have an effect upon the system, carbon monoxide-oxygen-carbon monoxide hemoglobin, opposite in direction to that produced by a change in the proportion of the carbon monoxide. Now the data on which the statements as to its toxicity have been based have all been gathered when carbon monoxide was breathed mixed with air containing 21 per cent. of oxygen. Unfortunately, however, when carbon monoxide is met with in dangerous quantities in the mines, the oxygen percentage is, as a rule, far below the normal. It seems to the writer, therefore, that under such conditions far lower proportions of carbon monoxide than those noted would produce serious results. It is regrettable that we have but little real data bearing on this point. A case has been reported,[41] however, in which several men lost their lives on entering an atmosphere containing 0.0023 per cent. of carbon monoxide and 4.874 per cent. of carbon dioxide. The oxygen percentage was not stated. As has been mentioned before, when considering the toxicity of an atmosphere, the action of no one of its constituents can be taken alone, but all must be considered together.

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[40] *Jour. Soc. Chem. Ind.*, vol. 15, p. 857.

As carbon monoxide is a poison for warm-blooded animals generally, its effect upon birds and mice has been taken advantage of to give warning of its presence. Haldane,[42] who has been instrumental in bringing this test to the notice of mining engineers, uses these words in describing it:

"The principle of the test is as follows: In small warm-blooded animals the rate at which chemical changes occur in a given body-weight is enormously greater than in large animals. Thus a mouse weighing about half an ounce consumes about fifteen times as much oxygen as half an ounce of the human body would consume in the same time. A reason for this difference is evident enough with bodies of the same shape and composition, but different sizes; the surface increases as the square of any corresponding diameter, but the mass as the cube. The bigger an animal is, therefore, the less surface will it have for a given mass, and the less rapidly will a given mass of it lose heat to the environment; or the less heat, and consequently the less oxygen, will a given mass of it require in order to maintain the normal body-temperature. Not only are the chemical changes in the small animal far more rapid, but the rate of respiration, circulation, etc., are correspondingly increased. It is difficult to count by the eye the rate of breathing in a mouse, and quite impossible to count its pulse-rate. By a photographic method of recording the electrical changes which accompany the heart-beat, Miss F. Buchanan, of Oxford, has recently shown that the pulse-rate in mice and small birds is from 700 to 1000 per minute.

"It follows that the small animal will absorb any poisonous gas far more quickly than a man will, and will therefore show symptoms of poisoning far sooner. It can, in fact, be employed to show what will ultimately happen to a man if he remains in the poisonous air. This, and this alone, is the principle of the test. The small animal is not, in the long run, more sensitive than a man to a given percentage of carbon monoxide; indeed, the opposite is almost certainly the case."

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[41] *Trans. Inst. Min. Eng.*, vol. 34, p. 564.

[42] *Trans. Inst. Min. Eng.*, vol. 38, p. 270.

The symptoms of poisoning by this gas are varied. When small quantities are breathed there may be drumming in the ears, with more or less frontal headache and nausea. As the poisoning proceeds, giddiness and lassitude will set in, followed by progressive loss of power in the lower extremities, merging into paralysis, which eventually invades the rest of the body. Synchronously with loss of muscular power the mental processes become deranged. Should the subject, however, inhale an atmosphere containing much carbon monoxide, almost instant insensibility will be the result. After recovery from exposure to this gas, severe pains in the head and extremities have been frequently noted, though a more serious after-effect is pneumonia.

The post-mortem appearances are characteristic. As carbon monoxide hemoglobin possesses a deep violet to cherry-red color, the face and lips have a remarkably fresh and lifelike appearance, very different from the bluish or livid pallor produced by a deficiency in oxygen.

Methane, the principal constituent of fire damp, is never found in the pure state. Beside the other components of an atmosphere, it is now generally conceded that it is accompanied by small proportions of higher hydrocarbons of the same, and unsaturated series. As these other hydrocarbons exert but little influence upon the properties of methane, their presence is more of academic than real interest. The gas is colorless, odorless, and lighter than air. Dickson and Coward give its ignition temperature in air at from 650° to 750°C. Air containing from 5 per cent. to 16 per cent. of methane will explode on ignition, though outside of these limits it may be dangerous because of its inflammability. It has been conclusively shown that methane finds its way into the air of a mine not only from reservoirs of the gas under pressure, but also more gradually from the coal substance itself. Though, as already pointed out, methane has in itself no physiological action, its indirect effect upon man through the dilution of oxygen which it brings about may be thus indicated:

TABLE VI.[44]

Percentage of fire damp present.	Effects on man.	Effects on lights.
1.0	Nil.	First indication of a cap.
2.0	Nil.	Well-formed cap.
5.5	Nil.	Lamp fires and goes out.
45.0	Breathing slightly deeper.	Lamp fires and goes out.
70.0	Life endangered.	Lamp fires and goes out.

An excess of nitrogen in mine air is due principally to the abstraction of oxygen by oxidizable substances. Black damp of this variety is distinguished by its lightness, being found in caps similar to fire damp, and is sometimes designated as "light air." Like methane, it is inert physiologically, acting merely as a diluent. Its action when carrying some carbon dioxide has been thus stated:

TABLE VII.[45]

Percentage of black damp (containing 87 per cent. of nitrogen and 13 per cent. of carbon dioxide) present.	Effects on man.	Effects on lights.
16	Nil.	Extinguished.
28	Breathing slightly deeper.	Extinguished.
50	Severe panting.	Extinguished.
66	Life edangered.	Extinguished.

Nitrogen peroxide is one of the products of the combustion of certain explosives. It is extremely poisonous when breathed. Peterson and Haines[46] state: "Habitually breathed in small quantities and great dilution, it produces severe chronic diseases. In acute poisoning, immediate dyspnea, tightness of chest, coughing, fainting, cyanosis, diarrhœa, and collapse. Death within forty hours, though symptoms of slight poisoning are delayed, in which case the first symptoms are headache, desire for fresh air, thirst, and then suddenly symptoms of aggravated character—distress of breathing, anxiety depicted on face, cold perspiration, protruding eyeballs, and spasmodic coughing, followed by vomiting."

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[44] *Trans. Inst. Min. Eng.*, vol. 13, p. 393.
[45] *Trans. Inst. Min. Eng.*, vol. 13, p. 393.
[46] Text-book of Legal Medicine and Toxicology, vol. 2, p. 676.

The presence of hydrogen sulphide in mine air may be brought about by the bacterial decomposition of organic matter, by the heating of coal by a mine fire, or by the action of organic matter on sulphates in solution. It is slightly heavier than air and possesses a strong odor, 0.01 per cent. being readily detected by the olfactory organ. This gas is even more toxic than carbon monoxide; it is stated that as little as 0.02 per cent. may have a toxic effect. Birds are especially sensitive to it, being killed by 0.05 per cent. "Breathed[47] in its pure state, this gas is immediately fatal. It acts upon all animals through all tissues, especially the lungs. If somewhat diluted, it produces nausea, giddiness, cold skin, labored breathing, irregular action of the heart, pains in the stomach, and death by coma or in violent convulsions, with tetanus and even delirium. In greater dilution sleepiness will be produced, the continued respiration of the gas proving fatal, sensibility not being restored. In exceedingly dilute condition it sometimes occasions febrile symptoms somewhat resembling typhoid. Air containing 0.05 per cent. was the limit that men could breathe (Lehmann). Sometimes symptoms appear after a considerable lapse of time after breathing the gas, and they may continue for some days."

The presence of sulphur dioxide is probably one of the surest indications we have of the presence of a mine fire. Fortunately the gas is so suffocating that ample warning is given of its presence. Though notably toxic in its action, workmen exposed to the gas may establish considerable tolerance toward it.

One plan of treatment is indicated for asphyxia brought about by the gases already described, except in the case of nitrogen peroxide, hydrogen sulphide, and sulphur dioxide. The victim should at once be brought into the fresh air, and artificial respiration by either the Sylvester or Shafer methods applied. If possible, a supply of pure oxygen should be used as an adjunct to the artificial respiration. Recently two apparatuses, the "Brat" and "Draeger Pulmotor," have been devised, with which air containing a high percentage of oxygen is forced into the lungs at a slight pressure, and then exhausted until a slight vacuum is

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[47] *Loc. cit.*, p. 671.

TABLE VIII.

COMPARISON OF THE PHYSIOLOGICAL ACTION OF AIR CONTAINING VARIOUS POISONS (LEHMANN).

The results are given in some cases in volumes p. ct. and in others in milligrams per litre	Quantity causing rapid death	Concentration which in ½ to 1 hour causes illness and danger to life	Concentration which produces no serious effect in ½ to 1 hour	Concentration which gives only slight symptoms after several hrs.	Author and reference
Hydrochloric acid gas.	....	0.15–0.20%	0.005 or at most 0.01%	0.001%	K. B Lehmann, Arch. f. Hyg. 5; Matt, Diss, Wurzburg, 1889.
Sulphurous acid......	....	0.04–0.05%	0.005%	0.002–0.003%	Orgata, Arch. f. Hygiene, 19. K. B. Lehmann and Wagschal (Dissertation).
Hydrocyanic acid.....	about 0.03%	0.012–0.015%	0.005–0.006%	0.002–0.004%	K. B. Lehmann and Wagschal (Dissertation).
Carbon dioxide.......	30%	about 6.0–8.0%	4.0–6.0%	2.0–3.0%	Emmerich, Friedlander and Herlerz. physiolog. Chem. 2.
Ammonia...........	....	0.25–0.45%	0.03%	0.01%	K. B. Lehmann, Arch. f. Hygiene, 5; 34.
Chlorine and bromine.	about 0.1%	0.004–0.006%	0.0004%	0.0001%	K. B. Lehmann, Arch. f. Hygiene, 7; Matt, loc. cit.
Iodine...............	....	....	0.0003%	0.00005–0.0001%	Matt, loc. cit.
Phosphorus trichloride	3.5 mg.	0.3–0.5 mg.	0.01–0.02 mg.	0.004 mg.*	K. B. Lehmann and Butjegin, Arch. f. Hygiene, 14.
Hydrogen phosphide..	....	0.04–0.06%	0.01–0.02%	....	K. B. Lehmann and Yokote, Arch. f. Hygiene, 14.
Hydrogen sulphide...	0.1–0.2%	0.05–0.07%	0.02–0.03%	0.01–0.015%	K. B. Lehmann, Arch. f. Hyg. 14.
Petroleum vapor......	....	....	15–25 mg.	5–10 mg.	
Benzene............	....	....	10–15 mg.	about 5 mg.	
Carbon bisulphide....	....	10–12 mg.	2–3 mg.	1–1.2 mg.	K. B. Lehmann, Arch. f. Hyg. 14.
Carbon tetrachloride..	300–400	about 150–200 mg.	about 25–40 mg.	about 10 mg.	K. B. Lehmann and Behr (Dissertation).
Chloroform..........	300–400	70	25–30 mg.	about 10 mg.	K. B. Lehmann and Behr (Dissertation).
Carbon monoxide.....	....	0.2–0.3%	0.05–0.1%	0.02%	Max Gruber, Arch. f. Hyg. 2.
Aniline and toluidine..	....	....	0.4–0.6 mg.†	0.1–0.25 mg.	K. B. Lehmann and Flogel (Dissertation).
Nitrobenzene.........	....	....	1.0 mg.‡	0.2–0.4 mg.	K. B. Lehmann and Zieger (Dissertation).

* Even as small a quantity as 0.0025 per cent. taken for about six hours per day sufficed to produce certain death.
† Quantities over 0.8 mg. per litre generally kill cats, if taken for more than five hours. Toluidine is somewhat less poisonous.
‡ The maximum quantity of nitrobenzene which can be brought into the air is about 1 mg. per litre; it never acts as a powerful poison when inhaled.

attained. With these latter appliances, of course, artificial respiration is unnecessary. The main difference between the Brat and the Draeger apparatus lies in the fact that the former is manipulated by taps under the control of the operator, while the latter is automatic in its action. The writer has had the opportunity, on various occasions, to apply these methods in cases of asphyxia, with most gratifying results. It is indeed remarkable how quickly a man, to all appearance dead, will regain consciousness when supplied with an excess of oxygen.

The primary object of so-called "rescue" or "breathing" apparatus is to permit the wearer to enter, safely and without inconvenience, an atmosphere incapable of supporting life. The various types of apparatus now in use may be divided into three classes: those in which oxygen is chemically generated within the apparatus; those in which liquid air is the source of the oxygen supply; and those in which the respired air is chemically purified or "regenerated," its deficiency in oxygen being made up from tanks of the compressed gas. It would be laborious and time-consuming to trace the gradual growth and improvement of these devices, nor does it lie within the scope of this paper to criticize or compare their commercial variations. Moreover, as the first two classes named have not been generally adopted, their discussion will be omitted. It will therefore be the object of these few closing paragraphs to point out certain desiderata which should be fulfilled by the successful breathing apparatus.

As the breathing apparatus is complementary to the wearer, it is necessary, before fixing conditions which it must fulfil, to understand very clearly the requirements of the wearer under varying working conditions. When a man breathes, the inspired air contains approximately 20.93 per cent. of oxygen, 79.04 per cent. of nitrogen, and 0.03 per cent. of carbon dioxide. About 4.50 per cent. of this oxygen enters into combination with the hemoglobin, being replaced by about 4 per cent. of carbon dioxide, the nitrogen remaining unchanged. Thus the expired air contains roughly 16 per cent. of oxygen, 80 per cent. of nitrogen, and 4 per cent. of carbon dioxide. Haldane[48] and Lorain Smith state that under working conditions a man will require from 50 to 60 litres of air per minute, though for a brief period after severe exertion this figure may reach 100. The author's experience fully bears out this statement. Of course, during periods of rest less than 50 litres of air per minute will be required. The breathing apparatus must therefore supply a minimum of two litres of pure oxygen per minute, must remove the carbon dioxide formed, and must at the same time circulate through the apparatus a minimum of 50 litres of air each minute.

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[48] The Physiological Effects of Air Vitiated by Respiration, *Jour. of Pathology and Bacteriology*, 1892, vol. 1, p. 168.

The ideal breathing apparatus should be as light as is compatible with strength and safety, as the wearer is laboring under severe mental stress, abnormal conditions, and oftentimes an insufficient air supply. It must be self-contained; that is, independent of any fixed base. It must permit the wearer to engage in severe muscular effort. The removal of carbon dioxide by the regenerator must be as complete as possible; a maximum of 2 per cent. should not be exceeded. As the fixation of this gas by caustic alkalies generates considerable heat, and as breathing heated air is extremely distressing, the air should pass through an efficient cooler after leaving the regenerator. The energy stored in the compressed oxygen should be utilized in circulating the air through the apparatus, thus relieving the lungs from this duty. A gauge should be provided which shall indicate distinctly and accurately for what length of time the apparatus may be used. The apparatus must be readily recharged. The charges must be so prepared that they may be stored for considerable lengths of time without deterioration. Inhalation and exhalation bags must be provided. The operation of the apparatus must be absolutely automatic, thus leaving the wearer's mind free. As the supply of air is constant, irrespective of the needs of the wearer, during periods of rest, an excess of oxygen will accumulate in the breathing bags. As the back pressure thus produced may cause considerable distress and even danger, a relief valve should be provided. The apparatus must be air-tight as regards the outside air, and must make an air-tight joint at the wearer's face. The wearer's eyes must be protected against smoke or irritant gases.

Breathing apparatus fulfilling most of these requirements has been constructed of two general types. In the one the air is supplied to the wearer through a mouthpiece, the nostrils being closed by a clip. In the other the head is encased by a helmet.

an air-tight joint being made about the face by a pneumatic cushion. There has been much acrimonious discussion in regard to the relative merits of these two types of equipment. It would seem to the writer, however, that there is but little profit in such discussion, as both have their advantages and disadvantages, while each has its own particular sphere of usefulness.

While a great volume of material has been written on the subject of the requirements of a man equipped with breathing apparatus, it has occurred to the author that a most important phase of the matter has been neglected; namely, the insensible respiration. In addition to the oxygen absorbed through the lungs, the blood is continually being supplied with oxygen through the skin. Gerlach[49] states that the ratio of oxygen supplied by the skin to that supplied by the lungs is as 1 is to 137, while Regnault[50] and Reiset set the ratio at 1 to 180. Should the wearer of a breathing apparatus enter an atmosphere low in oxygen, the inconvenience caused by the curtailment of the supply of this gas through the skin would probably be negligible. Should, however, the atmosphere contain much carbon monoxide, there might be considerable cause for apprehension, when we consider that carbon monoxide has over 200 times greater affinity for hemoglobin than oxygen, and practically the same diffusibility through animal membrane. Of course, this danger would only become pressing after long exposure to such an atmosphere. It is for this reason that the writer cannot too strongly urge those who may have direction of rescue parties to expose their men no longer than necessary to lethal atmospheres.

In conclusion the writer wishes to express his deep sense of gratitude to our secretary, Dr. Owens, for the great assistance he has rendered in furnishing data for this paper.

A PARTIAL LIST OF PAPERS AND BOOKS BEARING UPON THE SUBJECT OF AIR AND AIR ANALYSIS.

Rules for Recovering Coal Mines after Explosions and Fires, Garforth.
Explosive Mine Gases and Dusts, Chamberlin, *U. S. Geol. Sur. Bull.* 383.
The Use and Care of Mine Rescue Breathing Apparatus, Paul, U. S. Bureau of Mines, *Miners' Cir.*, No. 4.
Investigation of Mine Air, Foster and Haldane.

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[49] Die Physiologie der Haut, Roehig, Berlin, 1876.

[50] Human Physiology, Landois and Sterling, London, 2d ed., p. 886.

Technical Gas Analysis, Winkler and Lunge, 2d ed.

Methods of Testing Safety Lamps or Other Apparatus for the Detection of Combustible Gases and Vapor, Philip and Stenhouse, *Jour. Soc. Chem. Ind.*, vol. 30, p. 861.

A New Type of Automatic Inflammable Gas and Vapor Detector, Philip and Steele, *Jour. Soc. Chem. Ind.*, vol. 30, p. 867.

Report on Investigations Into the Composition of Gases Caused by Blasting in Mines, Mann, *Jour. Soc. Chem. Ind.*, vol. 30, p. 447.

Pathogenic Properties of the Gases Discharged by the Exhaust Pipe of Gas Engines, Dellepine, *Public Health*, 1911, p. 309.

The Estimation of Carbon Monoxide in Mine Gas, Weiskopf, *Jour. Chem. Met. Soc. S. Africa*, vol. 9, p. 258.

Determination of Oxygen by Absorption with Alkaline Pyrogallol Solution, Clowes, *Jour. Soc. Chem. Ind.*, vol. 15, p. 742.

Apparatus for the Determination of Carbon Monoxide, Goutal, *Ann. Chem. Anal. Appl.*, vol. 15, p. 1.

Breathing Apparatus for Use in Mines, Hill, *Trans. Inst. Min. Eng.*, vol. 35, p. 24.

Presence of Minute Quantities of Carbon Monoxide in the Air of Coal Mines, Mahler and Denet, *Comptes rend.*, 1910, vol. 151, p. 645.

The Combustion of Oxygen and Coal Dust in Mines, Blackett, *Trans. Inst. Min. Eng.*, vol. 7, p. 54.

The Prevention of Accidents in Mines, Kirkup, *Trans. Inst. Min. Eng.*, vol. 10, p. 1.

Detection and Estimation of Carbonic Oxide in Air, Clowes, *Jour. Soc. Chem. Ind.*, 1896, vol. 15, p. 742.

Pettenkofer's Method for Determining Carbonic Anhydride in Air, Letts and Blake, *Jour. Soc. Chem. Ind.*, vol. 15, p. 951.

Rapid Determination of Carbonic Acid in Air, Henriet, *Jour. Soc. Chem. Ind.*, vol. 15, p. 617.

Change in Composition Produced in Air by Flames and by Respiration, Clowes, *Trans. Inst. Min. Eng.*, vol. 9, p. 376.

The Nature of Some Coal Dusts and Mine Air from Colorado Mines, Ekeley, *Jour. Ind. Eng. Chem.*, vol. 3, p. 586.

Determination of Carbonic Oxide in Illuminating Gas by Iodine Pentoxide, Gill and Bartlett, *Jour. Ind. Eng. Chem.*, vol. 2, p. 9.

Analyses of Samples of Air from Representative Mines in Scotland, Gray, *Trans. Inst. Min. Eng.*, vol. 39, p. 305.

The Iodometric Determination of Small Quantities of Carbon Monoxide, Kinnicutt and Sanford, *Jour. Amer. Chem. Soc.*, vol. 22, p. 14.

The Physiological Effects of Air Vitiated by Respiration, Haldane and Smith, *Jour. of Pathology and Bacteriology*, 1892, vol. 1, p. 168.

A Modification of Pettenkofer Method for Carbon Dioxide, Marsden, *Chem. News*, vol. 101, p. 146.

A New Method of Testing for Gas in Mines with Safety Lamps, Cochrane, *Trans. Inst. Min. Eng.*, vol. 40, p. 272.

The Cunynhame-Cadman Gas-Detecting Device, Hailwood, *Trans. Inst. Min. Eng.*, vol. 39, p. 13.

Mining Explosives, Lewes, *Trans. Inst. Min. Eng.*, vol. 9, p. 320.

Adequate Ventilation and Noxious Gases, Thirkell, *Trans. Inst. Min. Eng.*, vol. 13, p. 389.

Methods of Gas Analysis, Hempel.

Elementary Chemistry for Coal Mining Students, O'Shea.

The Shaw Gas Tester, Bedson, *Trans. Inst. Min. Eng.*, vol. 13, p. 350.

Text-book of Legal Medicine and Toxicology, Peterson and Haines, vol. 2.

Technical Methods of Chemical Analysis, Lunge, vol. 1, Parts 1 and 2.

Investigations on the Composition, Occurrence, and Properties of Black Damp, Haldane and Atkinson, *Trans. Inst. Min. Eng.*, vol. 8, p. 549.

Analytical Chemistry, Treadwell, vol. 2.

Quantitative Chemical Analysis, Olsen.

Quantitative Chemical Analysis, Fresenius.

Quantitative Analysis, Clowes and Coleman.

Select Methods in Chemical Analysis, Crookes.

Determination of Fire Damp in French Collieries, Coquillon, *Trans. Inst. Min. Eng.*, vol. 13, p. 60.

Explosions in Coal Mines, N. W. and J. B. Atkinson.

Detection and Estimation of Inflammable Gases and Vapors, Clowes and Redwood.

Medical Jurisprudence, Taylor.

Manual of Practical Hygiene, Parkes.

Forensic Medicine and Toxicology, Woodman and Tidy.

Inorganic Chemistry, Newth.

Medical Jurisprudence, Wharton and Stille.

Les Asphyxies, Brouardel.

Practical Toxicology, Kobert, Trans. by Friedburg.

Human Physiology, Landois and Sterling.

Secretion and Absorption by the Skin, Reid.

Text Book of Physiology, Schafer, vol. 1.

Extinctive Atmospheres, Clowes, *Proc. Royal Soc.*, 1894, p. 56.

Handbook of Chemical Engineering, Davis.

Notes on Poisoning by Carbonic Oxide, Herman, *Jour. Soc. Chem. Ind.*, 15, p. 854.

The Use and Care of Breathing Apparatus, Habershon, *Trans. Inst. Min. Eng.*, vol. 33, p. 212.

Choke Damp: Disaster in an Upper Silesian Colliery, Steinhoff, *Trans. Inst. Min. Eng.*, vol. 34, p. 564.

An Examination of the Air of a Large Manufacturing City, Mabery, *Jour. Amer. Chem. Soc.*, vol. 17, p. 105.

Haulage at Wearmouth Colliery, Bell and McGowan, *Trans. Inst. Min. Eng.*, vol. 34, p. 221.

A New Apparatus for Rescue Work in Mines, Garforth, *Trans. Inst. Min. Eng.*, vol. 31, p. 625.

The Possibilities of Rescue Work in Connection with Mine Explosions and Fires, Haldane, *Trans. Inst. Min. Eng.*, vol. 39, p. 458.

Recherches sur le mode d'elimination de l'oxyde de carbone, *Comptes rend.*, 1891, p. 1232; 1892, p. 825.

Suggestions for the Organization of Colliery Rescue Brigades, Winborn, *Trans. Inst. Min. Eng.*, vol. 37, p. 81.

The Use of Breathing Apparatus at a Mine Fire in Cape Breton, etc., Gray and McMahon, *Trans. Inst. Min. Eng.*, vol. 37, p. 100.

The Use of Oxygen in Rescue Work in Collieries, *Amer. Gaslight Jour.*, vol. 67, p. 108.

On Poisoning by Gas: Its Prevention and Cure, Herman, *Jour. Soc. Chem. Ind.*, 15, p. 247.

The Comparison of Rapid Methods for Determining Carbon Monoxide, Dennis and Edgar, *Jour. Amer. Chem. Soc.*, vol. 19, p. 859.

On the Practical Use and Value of Colliery Rescue Apparatus and the Organization of Rescue Corps, Walker, *Trans. Inst. Min. Eng.*, vol. 36, p. 536.

The Walcher Pneumatophore and the Employment of Oxygen for Lifesaving Purposes, *Trans. Inst. Min. Eng.*, vol. 14, p. 575.

Use of Oxygen in Rescue Operations, Rossner, *Trans. Inst. Min. Eng.*, vol. 14, p. 648.

A Study of the Relative Poisonous Effects of Coal and Water-Gas, Sedgwick and Nichols, Sixth Annual Report of Massachusetts State Board of Health, 1885.

Fatal Poisoning by Carbon Monoxide, Mason, *Jour. Amer. Chem. Soc.*, vol. 10, p. 176.

Neupert Rescue Apparatus, Mayer, *Trans. Inst. Min. Eng.*, vol. 16, p. 580.

Discussion of Habershon's Paper on "The Work of a Joint Colliery Rescue Station," *Trans. Inst. Min. Eng.*, vol. 28, p. 254.

Liquid Air and its Use in Rescue Apparatus, Simonis, *Trans. Inst. Min. Eng.*, vol. 32, p. 534.

The Pneumatogen—The Self-generating Rescue Apparatus—Compared with Other Types, Cremer, *Trans. Inst. Min. Eng.*, vol. 32, p. 51.

Demonstration of Rescue Apparatus—Felling, August 31, 1907, Austin, *Trans. Inst. Min. Eng.*, vol. 35, p. 210.

Saving Life in Colliery Explosions, Bailey, *Trans. Inst. Min. Eng.*, vol. 8, p. 133.

Discussion of Simonis's Paper on "Liquid Air and Its Use in Rescue Apparatus," *Trans. Inst. Min. Eng.*, vol. 33, p. 2.

Discussion of Simonis's Paper on "Liquid Air and Its Use in Rescue Apparatus," *Trans. Inst. Min. Eng.*, vol. 34, p. 148.

Rescue Apparatus for Use in Mines, Bains, *Trans. Inst. Min. Eng.*, vol. 34, p. 72.

Rescue Apparatus and the Experiences Gained Therewith at the Courrieres Collieries by the German Rescue Party, Meyer, *Trans. Inst. Min. Eng.*, vol. 31, p. 575.

Determination of Methane and Hydrogen by Explosion, Gill and Hunt, *Jour. Soc. Chem. Ind.*, 15, p. 295.

The Safety Lamp as an Instrument for the Detection and Estimation of Fire Damp, Winstanley, *Trans. Inst. Min. Eng.*, vol. 40, p. 338.

Fire Damp: Its Composition, Detection, and Estimation, Gray, *Trans. Inst. Min. Eng.*, vol. 39, p. 286.

Fire Damp Caps and the Detection of Fire Damp in Mines by Means of Safety Lamps, Whalley and Tweedie, *Trans. Inst. Min. Eng.*, vol. 38, p. 509.

Notes on Small Contrivance to More Easily Detect Fire Damp, Blackett, *Trans. Inst. Min. Eng.*, vol. 37, p. 276.

Method of Determining Whether Fire Damp be Pure Methane, Coquillon, *Trans. Inst. Min. Eng.*, vol. 14, p. 633.

Fire Damp Explosives, Presidential Address, *Trans. Inst. Min. Eng.*, vol. 16, p. 91.

Fire Damp: The Courrieres Explosion, Atkinson and Henshaw, *Trans. Inst. Min. Eng., vol.* 32, p. 439.

Rescue Work in Mines, with a Determination of Apparatus in Use, Hill, The Royal Sanitary Institute, March 14, 1911.

Grehaut Fire Damp Indicator, *Trans. Inst. Min. Eng.*, vol. 34, p. 554.

Fire Damp Explosion at the Lierin Colliery, France, *Trans. Inst. Min. Eng.*, vol. 34, p. 555.

Discussion of Prof. Lewes's Paper on "Mining Explosives," *Trans. Inst. Min. Eng.*, vol. 10, p. 454.

The Causes of Death in Colliery Explosions, Haldane, *Trans. Inst. Min. Eng.*, vol. 34, p. 502.

Determination of Carbon Monoxide in Mine Air, Fillunger, *Trans. Inst. Min. Eng.*, vol. 31, p. 713.

Fire in a Colliery at Petrzkowitz, Silesia, Triebel, *Trans. Inst. Min. Eng.*, vol. 31, p. 724.

Discussion of Letham's Paper on "Notes on the Detection and Estimation of Inflammable Gases in Mines by Means of Flame Caps," *Trans. Inst. Min. Eng.*, vol. 31, p. 246.

Action of Carbon Monoxide and Coal Dust in Causing Colliery Explosions, Orsman, *Jour. Soc. Chem. Ind.*, vol. 15, p. 319.

Testing for Carbon Monoxide in Combustion with Fires and Explosions in Mines, Haldane and Douglas, *Trans. Inst. Min. Eng.*, vol. 38, p. 267.

Carbon Monoxide Detector, *Trans. Inst. Min. Eng.*, vol. 37, p. 587.

The Detection and Estimation of Carbon Monoxide in Air, Gautier, *Trans. Inst. Min. Eng.*, vol. 16, p. 571.

Observations on the Relation of Underground Temperature and Spontaneous Fires in the Coal to Oxidation and to the Causes Which Favor It, Haldane and Meachem, *Trans. Inst. Min. Eng.*, vol. 16, p. 457.

THE DETERMINATION OF MOISTURE IN FUEL.

BY

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WHEN purchasing and utilizing coke and coal, the presence of moisture in the material purchased is objectionable for at least two reasons: First, the water is purchased and paid for as carbon; and, second, the water so purchased necessitates the combustion of some of the carbon to drive it off from the fuel bed. Thus we are not only paying for a worthless material as good carbon, but we are penalized as well.

Bituminous coal, and frequently coke, is received at destination in open cars of the gondola type, and in transit is liable to be soaked by heavy rains, sleet, or snow. Usually the shipment is paid for by railroad weights, and if the car was weighed before the contents were water-soaked, the purchaser suffers no loss from the first objection named; he must, however, still encounter the cost of boiling off the water accumulated in transit.

In order to give an idea of the amount of water which some well-known fuels will absorb, samples of oven coke, run-of-mine steam coal, and Fairmount gas coal were subjected to the following test (see Appendix No. 1):

The fuels were wet down with a hose, drained by being placed in perforated galvanized iron pails, and weighed. These pails were then hung in a normal atmosphere at a temperature of 70° F. and weighed at intervals of one day until ten days had expired. The details of this test prove that in the case of oven coke the wet sample lost 14.6 per cent. of its weight, due to the evaporation of the moisture which it originally contained. With the steam coal, the loss was 13.3 per cent.; but with the Fairmount, screened gas coal, the aggregates consisting of clean cubes about egg size, the contained moisture was only 2.2 per cent. Other tests of retort coke from coal gas plants show that this coke will absorb water to the extent of 22 per cent. of its dry weight if exposed to rain.

It is evident, therefore, that unless we have some knowledge of the content of moisture in the fuel, we may pay 15 per cent. more for a ton of carbon in the case of wet fuel than we do in the case of dry fuel. The significance of this possibility becomes more apparent when we consider the case of a carburetted water gas plant manufacturing 10,000,000 cubic feet of gas a day, with a consumption of 150 tons of coke daily. The value of this dry coke at current prices is $675. If, during the process of quenching, or at any time previous to weighing, it has absorbed 10 per cent. moisture, the increased cost to the gas company over and above what it would pay for dry coke is $75 a day, or, in a year of 365 days, $27,375. In addition to this expense, the cost of boiling off this water from the fuel after it is put into the cupolas will be, in the case of a plant discharging the stack gases at a temperature of 1500° F., 2 per cent. of the total fuel consumed. This would add another expense of $13.50 per day, or $4,927.50 yearly.

Referring again to the test of the various samples of fuel, when soaked with water and allowed to dry, it will be noted that there was a gradual dissipation of the moisture from the start of the test until the end. In other words, if a sample of wet coke or coal is selected at the mines or at the car and transported any appreciable distance or for any considerable time, there will be, if protected from further wetting, a loss of moisture in the sample. To illustrate this, I quote from a letter received from Mr. C. J. Ramsburg, Assistant Engineer of Works of the Philadelphia Gas Works:

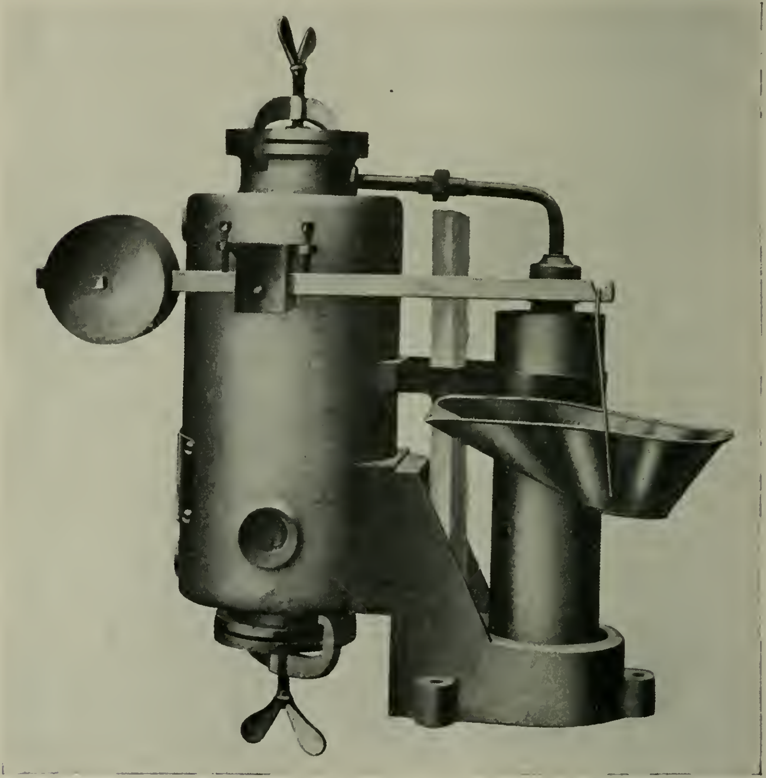
> "So far, the use of the moisture determinator has been restricted to the testing of coke receipts, in which we have proved that the laboratory analysis of the coke is no criterion of the condition of the coke as received by us. For example, on October 3d a barge of coke was received, the average sample of which was taken during the unloading, and, tested in the moisture determinator, showed 11.6 per cent. moisture. The analysis of the sample taken at the same time, when conveyed to the laboratory, crushed and sampled according to the usual laboratory system, showed only 2.1 per cent. moisture."

Numerous other instances of the same general nature could be cited.

Where very high guarantees are made of the consumption of carbon in water gas apparatus, the determination of the water in the fuel becomes a very important matter. For example, the presence of 10 per cent. of moisture may readily result in a failure to obtain the guarantee, not only because it interferes with the proper working of the apparatus, but because it is weighed into the apparatus as carbon. Under these circumstances, great difficulty has been experienced in obtaining the content of moisture in the fuel actually charged into the machine, on account of the fact that the laboratory is frequently at a distance from the generating house and considerable time elapses between the taking of the sample and its analysis in the laboratory. These conditions always operate against the guarantor of results, as there is invariably a loss of moisture, where much is present during the transportation and handling of the sample, for which the operator gets no credit. In the standard method of determining moisture in coal and coke, opportunity is also offered for the escape of moisture to the atmosphere after the sample is received at the laboratory and before the determination actually begins. Usually the finely-ground sample is placed in an open porcelain or platinum crucible, weighed, and dried for one hour in any good form of air bath. Upon removal from the oven, the crucible is covered and cooled in a desiccator and again weighed. The loss in weight gives the moisture. It will be noted that before the initial weight is taken the sample has been selected on the generator house floor, transported to the laboratory, and finely ground. During all this period there is a continual loss of moisture, the amount depending somewhat upon the humidity of the atmosphere.

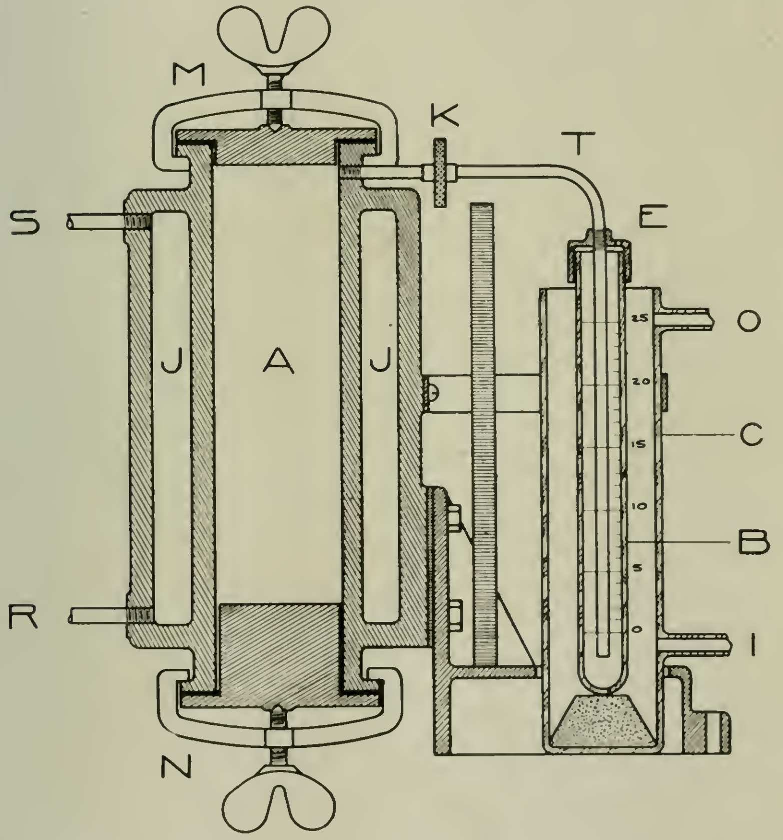
It was on account of the difficulties described above that an effort was made to devise a simple and fairly accurate means of making moisture determinations at the place where the fuel is consumed. The result is the moisture determinator as shown assembled in Fig. 1 and in section in Fig. 2. In this instrument a steam jacket is used to drive off the moisture, the temperature of the jacket being determined by the steam pressure, and maintained at such a point that, while the moisture is driven off, the volatile combustible will be retained in the fuel chamber. *A* is the fuel chamber in which is deposited the sample of fuel to be examined for moisture. Its volume is such as conveniently to hold the ample sample of one pound of the fuel. *B* is a graduated glass tube surrounded by a reservoir *C* containing cool water, which latter may be introduced at *I* and be removed at *O*, thus forming a condenser. The graduations of the tube *B* are of such magnitude that when 1 per cent. by weight of the sample is driven off in the form of moisture and condensed in the tube the volume of the condensed water vapor driven off will just equal the volume between any two graduations on the tube. Around the chamber *A*, forming a jacket, is the annular space *J*. Into this space steam at any desired temperature is introduced at *S* and discharged at *R*. *M* and *N* are means for filling and emptying the chamber *A*, and *K* is a ground joint union which permits the graduated tube *B* to be disconnected and emptied after the determination is completed. The apparatus is operated as follows:

FIG. 1.



The determinator may be erected on any convenient wall or table, preferably as close as possible to the point where the fuel is being consumed, thus eliminating to a great degree any change in the moisture content in the sample between the time the sample is taken and the time the moisture content is determined.

FIG. 2.



A balance shown in Fig. 1 is provided with the determinator, by the aid of which one pound of the fuel is introduced into the chamber *A*. Steam is then turned on the jacket *J*, and by the aid of a pressure gauge on the pipe *S* the temperature is maintained at any convenient degree, preferably at 230° F., as at this temperature the water may be driven off without the volatilization of any of the hydro-carbon vapors. A cock on the discharge pipe *R* should be left slightly open so that any water condensed in the chamber may be carried off, and thus prevent it from affecting the temperature of the jacket. Previous to turning on the steam, water circulation has been started through the receptacle *C* by means of the pipes *I* and *O;* also, sufficient water has been introduced through the hole *E* to bring up the level in the tube *B* to the zero mark. Upon the turning on of the steam through the pipe *S* the determination begins and the instrument may be left without any attention for the space of an hour, when it will be found that practically all of the moisture is driven off from the sample and appears in the tube *B* as water, in per cents. of the original weight of the sample.

In addition to its other merits, the apparatus possesses the following two very important ones:

First: In its use but one weighing—that of the moist sample of fuel—is necessary, and any small error in this weighing can produce only a correspondingly small error in the moisture percentage result; in the ordinary method, on the other hand, two weighings—one of the moist and one of the dry sample—are required, and even a small error in one of these weighings, and consequently in their difference, which is supposed to represent the weight of moisture, may cause a very large error in the determination of percentage of moisture.

Second: The moisture in the fuel is condensed to water, is visible, and hence its existence is indisputable.

Before this instrument was put into service a calculation was made to determine theoretically what would be its characteristic error. This calculation is given in Appendix No. 2, and shows that theoretically the error should be about .13 per cent.; that is, the true content of moisture would be .13 per cent. greater than the indicated content, owing to the volume of the voids in the sample of fuel and of the pores of the coke itself. To check this calculation, definite quantities of moisture were added to dry samples of coke and the samples examined in the determinator, with the result that the practical error agreed with the theoretical error.

Although this instrument was devised particularly for use in obtaining high guarantees connected with the combustion of coke and coal, it has been found useful in various ways. For instance, in a coal gas plant where the yield of gas, ammonia, tar, etc., per pound of coal is figured in great detail, it is found that the uncertainty introduced by the presence of a variable amount of moisture is very annoying. With the use of the moisture determinator, however, this uncertainty is to a large extent eliminated. In one case it was found that the content of moisture in gas coal as weighed into the bins averaged as high as 9 per cent. for a period of some months. If this content of moisture had not been known, the poor results from the use of such coal would have widely misled the operating engineer.

New uses for this instrument are constantly being suggested, among them the determination of water in metallic ores, and water and light oils in tar. At present it does not seem practicable for everyone to purchase coal on a B. T. U. basis, but the United States Government has adopted this practice, and, as it is without doubt the equitable way of purchasing fuel, we may expect before many years to see it generally adopted. In this case the determination of the moisture in the shipment purchased is of equal importance with the determination of ash and other impurities, and the field of usefulness for the moisture determinator will probably be greatly broadened.

APPENDIX NO. 1.

A. Camden oven coke egg size.
Weight of dry sample.................................... 9.9 lbs.
B. Quemahoning boiler coal, run-of-mine.
Weight of dry sample.................................... 16.7 lbs.
C. Fairmount gas coal screened; egg size.
Weight of dry sample.................................... 16.3 lbs.

	Per cent of Moisture		
Elapsed Time	A.	B.	C.
Start	14.6	13.3	2.2
18 hours	11.3	9.6	1.2
3 days	7.4	5.9	.9
4 days	6.6	4.6	.7
6 days	4.5	2.3	.6
7 days	3.3	1.7	.6
10 days	2.5	1.3	.6

Appendix No. 2.

Moisture determinator.

Chamber = 2 – ⅞″ diam. × 12″ = 6.4918 sq. in. × 12″ = .0451 cu. ft.

Capacity of Chamber: Allowance 37 per. cent. = voids in coke = .0451 cu. ft. × .37 = .0167 cu. ft. = volume containing moisture at finish.

212° F.
459.4 80 lbs. press. = 95 lbs. absolute = 323.9° F.
671.4° F. Absolute temp. 459.4
783.3° F. Abs.

$.0167 \text{ cu. ft.} \times \frac{671.4}{783.3} = .0143$ cu. ft. steam.

1 cu. ft. steam, atmospheric pressure = .03794 lbs.
.0143 × .03794 = .0005425 lbs. steam remaining at finish of operation.
1 cu. in. H_2O at 60° F. = 16.4 cu. centimetres.
1 cu. in. H_2O at 60° F. = .0361 lbs.
.0005425 lbs. divided by .0361 = .01503 cubic inches.
.01503 cu. in. × 16.4 = .2465 c.c. H_2O remaining at finish, due to voids.

Coke as per sample = 50 per. cent. porosity.
37 per. cent. voids.
87 per. cent. total.

.0451 cu. ft. capacity × .87 = 0.039237 cu. ft. = volume due to porosity and voids $= \frac{.039237}{.0167}$ or 2.35 times the above.

.0005425 lbs. steam remaining × 2.35 = .001275 lbs. steam $= \frac{.001275}{.0361} =$ .03531 cu. in.

.03531 cu. in. × 16.4 c.c. = .579 c.c. H_2O remaining.
1 c.c. H_2O at 60° F. = 1.001 grains × .579 = .5795 grains.

Assumption 1 lb. coke = 453.6 grains gross weight $\frac{.5795}{453.6} = .0012775 =$ .12775 per cent. = Loss.

The Resistance of Iron to Rust in Concrete. Anon. (*Rev. Scientifique*, xlix, 1, 23.)—An old building in Hamburg was recently demolished, from which the behavior of iron enclosed in concrete can be judged. This was an old gasometer, the foundations of which rested on several pillars. The iron anchors were immersed in cement grouted to a good thickness. The 60 bars, each 2½ metres long, which formed the anchors, were examined, and were found to be perfectly well preserved. They still showed their outer bluish skin and no trace of rust. This gasometer was built between 1852 and 1855, so the iron bars had been fully 50 years in the concrete. This protection from rust can be explained by the fact that the dampening of the concrete had produced a strongly alkaline reaction, and that iron, when surrounded by alkali, is inoxidizable.

THE INTERNATIONAL ELECTROTECHNICAL CONGRESS OF TURIN.

A Brief Report to the Franklin Institute, Subject to the Official Reports of the Congress,

BY
A. E. KENNELLY,
(Harvard University)
An Official Delegate of the Institute.

The International Electrotechnical Congress, which was held at Turin, September 10–17, 1911, was organized under the auspices of the Associazione Elettrotecnica Italiana (A. E. I.) and of the Italian Committee of the International Electrotechnical Commission (I. E. C.), in relation to the Turin-Rome International Industrial Exhibition, which celebrated the semi-centennial anniversary of Italy's political union.

The organization consisted of:

(1) A Committee of Honor, headed by H. R. H. the Duke Degli Abruzzi, and 28 members, principally either officers of the Italian government or of the Turin municipality, but including Prof. Elihu Thomson, the President of the I. E. C.

(2) A Committee of Organization of 30 members, headed by Prof. L. Lombardi, the president of the A. E. I., and comprising the presidents of the various sections of that society, as well as the presidents of the national committees of the I. E. C. An American sub-committee was formed of the following members: J. W. Lieb, Jr. (president), and Messrs. A. E. Kennelly, C. O. Mailloux, T. C. Martin, H. G. Stott, and S. W. Stratton. The Congress secretaries were Messrs. C. A. Curti and G. Semenza.

(3) An Executive Committee of 23 members, headed by Prof. G. Grassi, the president of the Turin Section of the A. E. I., and enrolling a number of active members of that section.

Notice was sent in 1910 to the various national committees of the I. E. C. that the Congress would be divided into eight sections, and offering a list of 31 official electrotechnical subjects, on which reports were requested, in advance, from specialists in the various countries, which reports should be laid before the Congress as the basis of its discussions. Papers were also invited, to be offered for acceptance in advance. The number of such accepted and presented papers amounted to 49, making a total of 80 communications read at the sessions, from writers in 14 different countries, representing 10 different languages. The American communications were 11 in all. The complete series of papers is expected to be printed in the Proceedings of the Congress.

Four official languages were selected—English, French, German, and Italian—in any of which a communication might be offered or a discussion contributed; but English, German. and Italian papers had to be accompanied by a brief French *resumé*. In the official notices and bulletins of the Congress only the French and Italian languages were used, side by side.

The total number of full-membership adhesions to the Congress printed up to September 15 was 453, while the total registrations of all classes exceeded 650.

The following officers were elected at the opening session on September 10:

President—Prof. Luigi Lombardi.

Vice-presidents—Prof. Guido Grassi, Ing. Emanuele Jona.

General Secretary—Ing. Guido Semenza.

Honorary Vice-presidents—

Antonio Pacinotti for Italy.
Silvanus P. Thompson and Alexander Siemens for England.
Gano Dunn, president of the A. I. E. E., for America.
Paul Janet for France.
Karl Strecker for Germany.
Alfred Graf for Austro-Hungary.
Pierre Ossactchy for Russia.
Gustave L'Hoest for Belgium.
Behn-Eschenburg for Switzerland.
De La Pena for Spain.
Poulsen for Denmark.

The following section officers were elected:

Section	*Subject*	*President of Section*	*Vice-Presidents*	*Secretaries*
I.	Electrical Machines and Transformers	Boucherot (Francia)	Morelli (Italia) Feldmann (Olanda)	C. Palestrino
II.	Electrical Systems and Networks	De Bast (Belgio)	Ferraris (Italia) Landry (Svizzera)	Del Buono Boccardo
III.	Instruments and Measurements	Kennelly (U. S. A.)	Dina (Italia) Armagnat (Francia)	Emanueli Barbagelata
IV.	Lighting and Heating	Rossander (Svezia)	Mengarini (Italia) Sharp (U. S. A.)	Danioni
V.	Electric Traction	Mailloux (U. S. A.)	Sartori (Italia) Barnet Lyon (Olanda)	Fenzi Ponti
VI.	Telegraphy and Telephony	O'Meara (Inghilterra)	Larsen (Danimarca) Di Pirro (Italia)	Bellini
VII.	Electrochemistry and Metallurgy	Beckmann (Germania)	Miolati (Italia) Rumi (Italia)	
VIII.	Tariffs and Taxation	Arno (Italia)	Dettmar (Germania) Bonghi (Italia)	Botto Giulietti

Certain resolutions were presented by the sections, were printed in the official bulletin, and set for consideration at the plenary sessions of the Congress as a whole. The following is a synopsis of the more important resolutions thus adopted by the Congress at large:

(1) That the International Electrotechnical Commission is requested to accept the task of organizing future electrotechnical congresses, so far as concerns their dates, places of meeting, and objects, the details of the organization of each Congress being confided to the electrotechnical committee of the country in which the congress is to be held, with the assistance of its technical societies if necessary.

> (This official request was duly received and accepted by the Council of the I. E. C., in session at Turin, on September 13.)

(2) That the International Electrotechnical Congress of Turin compliments the American Institute of Electrical Engineers on the practice it has adopted of inserting in its publications the metric equivalent value, in parentheses, after each expression of values in English measure.

And since this procedure greatly facilitates the reading of those publications in all the countries using the metric system, while constituting a worthy example towards, and in view of, the much-desired complete international unification of weights and measures;

Resolved, That the technical societies of all countries in which the metric system is not yet official are invited to follow the above-mentioned example of the American Institute of Electrical Engineers.

(3) That industrial traction accelerations be expressed in kilometres per hour per second (or equivalent local national terms, such as miles per hour per second, or versts per hour per second).

(4) That the Congress favors the appointment of an International Commission for the general study of systems of illumination and of all technical problems connected with illumination.

A meeting of the A. E. I. was held on September 13, largely attended by Congress members, to celebrate the semi-centennial anniversary of Signor Pacinotti's invention of his ring-armature for dynamo machines, and to present to him a testimonial of recognition and esteem. President Lombardi presented to Signor Pacinotti a handsomely-illuminated copy of his original paper on the ring-armature machine, originally printed in *Il Nuovo Cimento* for 1865. A brief reply of thanks was made by Signor Pacinotti, which was received with acclamation.

Technical visits were paid by parties of Congress members to electric installations of interest in the vicinity, under the escort of their Italian hosts.

At the closing plenary session of September 16 the thanks of the Congress were voted to the Committee of Organization, and especially to President Lombardi and Secretary Semenza, for their very successfully performed services. The various national delegations joined heartily in these recommendations. The thanks of the Congress were also cordially expressed to the city of Turin, to the Italian National Committee, and to their Italian hosts generally, for the many courtesies and entertainments received by the members during their very pleasant stay at Turin. One of the many such entertainments was a dinner to the delegates on the summit of the hill "La Superga," about 400 metres above the city and some 10 kilometres to the north. The view of the Piedmontese Alps so obtained, by the light of sunset, above the intervening plain, was something never to be forgotten.

The American delegation consisted of H. B. Brooks, Gano Dunn, G. Faccioli, R. O. Heinrich, A. E. Kennelly, C. O. Mailloux, C. H. Sharp, E. Thomson, and Philip Torchio. This delegation was also separately entertained at a luncheon given by the Italian committee.

As a whole, the Congress was a great success, to which the prevailing fine and pleasant weather lent much aid. The Turin Exposition also added very notably to the interest of the meeting.

CORRECTION.

"THE Coefficient of Expansion of Tar," by John Morris Weiss," vol. clxxii, page 277,

$$\text{“Specific gravity: } t^\circ/t^\circ = \frac{c - a}{(b - a) - (d - a)}\text{”}$$

should read:

$$\text{“Specific gravity: } t^\circ/t^\circ = \frac{c - a}{(b - a) - (d - c)}\text{”}$$

Unsolved Problems in Electro-plating. G. B. HOGABOOM. (*Sci. Amer. Sup.*, 1846, 320.)—The problems most desired to be solved are: An electrolyte that will remove the fire-scale from brass; one that will produce a bright or a matte surface in place of using the present acid dips; an electric cleaner that will saponify the grease and dissolve it instead of drawing it to the top, whence it has to be constantly removed to prevent it adhering again to the work as the latter is removed from the solution; a heavy deposit of lead on the inside of iron pipes to prevent rapid corrosion; a method of coating electrogalvanized iron or steel with decorative metals without destroying the rust-resisting properties of the zinc; an alkaline nickel-silver solution that can be worked with a low voltage; a method of etching steel without destroying a resistance film of gelatine. Some alkaline substance to replace potassium cyanide would be universally welcomed.

Process for Increasing the Efficiency of Titanium. T. GOLDSCHMIDT. (*Ger. Pat.* 235, 461, 1909.)—In refining iron or steel by the addition of ferro-titanium it has not been found possible to attain good results with alloys containing more than 10 to 15 per cent. of titanium. However, if aluminum be added as a third component to the alloys, much richer titanium alloys can be used. Especially good results have been obtained with an alloy containing 24 to 25 per cent. of titanium and 3 per cent. of aluminum.

A Physical Interpretation of Non-Compensated Heat. L. DÉCOINTRE. (*Mon. Scient.*, lxxv, 551.)—It has been previously shown that the non-compensated heat disengaged in a reaction in which there is no such phenomenon as electrical conduction, ionization or atomic disaggregation may be identified with the *Siemens heat* which accompanies the electrification of the volume elements of the system. For each volume element this heat can be expressed by the sum of the terms proportional to the squares of the speeds of the sensible, independent reactions. It disappears when these speeds are infinitesimally small or zero. To generalize this interpretation of non-compensated heat it must first be observed that the electrification of a volume element results actually from the electrification of the atoms that it includes. This *Siemens heat,* then, must be applied to the electrification of the atoms. If the electronic point (considering the atom as an assemblage of electrons) is admitted, the electrification of an atom must be recognized as intrinsically caused by a certain deformation of the atomic edifice, a deformation to which the *Siemens heat* is to be attributed. This hypothesis may be expressed by saying that "every reaction accomplished with a finite speed is accompanied by a disengagement of heat proportional to the square of the speed of the reaction." As a further step by *Siemens heat* will be meant that heat of atomic deformation that will represent the non-compensated heat disengaged in every transformation not accompanied by conduction, by ionization or by atomic disintegration. If the preceding hypothesis is accepted, then it must be admitted that "the loss of an electron is always immediately followed (and, moreover, generally preceded) by a disengagement of *Siemens heat.*" Similar reasoning seems applicable to the finite changes which accompany either the recombination of a negative electron with a positive atom, or the formation, the rupture and re-combination of the ions, or the splitting up of an atom into several others with or without the simultaneous liberation of ions and electrons.

Hence the production of *Siemens heat* appears to be a very general fact; and, moreover, it appears that under any circumstances it can be identified with the non-compensated heat of thermodynamics.

It seems difficult, if not impossible, to support this hypothesis by any demonstration or general verification. All that can be done, apparently, is to ascertain in each particular case whether it can be reconciled to the facts.

Boric Acid in Nickel-Plating. ANON. (*Brass World*, vii, 9, 330.)—The use of a large amount of boric acid in a nickel-plating solution is found to be advantageous. The nickel deposit is whiter and brighter than when a smaller amount is used, and the pitting is reduced. About 5 ounces of boric acid to 1 gallon of nickel solution are found suitable.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, October 18, 1911.)

Hall of the Franklin Institute,
Philadelphia, October 18, 1911.

President Walton Clark *in the Chair.*

Additions to membership since last report, 10.

The amendment to the By-laws relating to the election of the Board of Trustees, presented at the September meeting, was unanimously adopted.

Following the meeting of the Institute for the transaction of this business, a joint meeting was held with the American Society of Mechanical Engineers, Mr. Walton Clark, President of the Institute, and Mr. T. C. McBride, Chairman of the Philadelphia Section, jointly presiding, at which an important paper on "The Practical Application of Scientific Management to Railway Operation" was read by Mr. Wilson E. Symons, of Chicago. Mr. Symons dealt exhaustively with the subject of railway economics and the practical application of scientific methods to railway work, especially in the repair and motive power departments of railroads.

An interesting discussion followed the reading of the paper, in which the following gentlemen took part: Messrs. Webb C. Ball, Cleveland, O.; T. H. Clarke, Baltimore, Md.; A. L. Conrad, Chicago, Ill.; Harrington Emerson, New York City; Frank B. Gilbreth, New York City; George R. Henderson, Philadelphia; B. B. Milner, Wilmington, Del.; James Shirley Eaton, New York City; Charles Day, Philadelphia; Walter V. Turner, Pittsburgh, Pa., and S. M. Vauclain, Philadelphia.

Adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of proceedings of the Stated Meeting held Wednesday, October 4, 1911.)

Hall of the Franklin Institute,
Philadelphia, October 4, 1911.

Dr. George A. Hoadley *in the Chair.*

The following reports were presented for first reading:

No. 2472.—Minnick's Concrete Piles. Advisory. Adopted.

No. 2499.—Santo Vacuum Cleaner.

No. 2506.—Sherardizing Metallic Surfaces.

The following was presented for final action:

No. 2477.—Granbery's Stadia Rod. Referred back to Subcommittee.

R. B. Owens,
Secretary.

SECTIONS.

Section of Photography and Microscopy.—The first meeting of the season was held in the hall of the Institute on Thursday, October 5, 1911, at 8 P.M., with Dr. Henry Leffmann in the Chair. Three hundred members and visitors were present, including a large number of professional photographers.

Mr. G. Dietz, of the Multispeed Shutter Company, of New York, delivered an instructive and entertaining lecture on "High-Speed Photography," especially in connection with an electric flashlight attachment, enabling the operator to manipulate the shutter and flash simultaneously, producing a picture with an exposure as brief as 1/2000 of a second. He explained the mechanism of the shutter in detail, dwelling on the reasons why such a construction should be capable of great speed, permitting one to take high-speed photographs at night.

Some pictures taken by Mr. Jennings in daylight showed a sharply-defined baseball in flight between the bat and first base.

Many experiments were made, the negatives hastily developed, lantern slides made from the still wet plate and shown on the screen, illustrating the subject. The times of the exposures were not tested, but the rapidity was so great as to give a sharp negative from the fluttering wings of two chickens thrown in the air. An athlete jumping over a table was caught in the air over the table and sharply defined, while with an ordinary flash the man was shown as an unrecognizable smudge. Several portraits and groups were taken in 1/200 of a second.

The speaker explained fractional development, by which the exposed plate is first treated with reducer and then with the alkaline solution, suggesting the following formula, which may be modified so as to produce soft or hard effects, as desired:

SOLUTION 1.

30 ounces water.
2 drachms edinol.
2 drachms hydroquinone.
2 ounces sulphite, dry.

SOLUTION 2.

30 ounces water.
2 ounces carbonate of soda, dry.
Temperature, 65 to 70°.
Plates, 1¼ minutes in each.
Films, 1 minute in each.

Adjourned.

J. W. RIDPATH,
Secretary.

Electrical Section.—A joint meeting of this Section and the Philadelphia Section of the American Institute of Electrical Engineers was held on Thursday evening, October 12th.

The meeting was called to order by President Walton Clark, who invited Mr. H. C. Snook, Chairman of the Philadelphia Section of the American Institute of Electrical Engineers, to take the Chair.

Major George Owen Squier, of the Signal Corps, U. S. Army, was then introduced, and presented an interesting communication on "Electrical Methods of Intercommunication for Military Purposes."

The construction of telephone and telegraphic lines and cable laying done by the Signal Corps in the Philippine Islands, Porto Rico, Alaska, and elsewhere were described; range finding, signalling, and distant control of fire were also explained.

The subject was fully illustrated by numerous lantern slides made in the field.

By special request, at the close of the lecture, Major Squier also described his recently-developed system of multiplex telephony.

In the discussion which followed the paper Drs. Goodspeed, Northrup, and others participated.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. FREDERIC ROSENGARTEN, Ninth and Parrish Sts., Philadelphia.
MR. WM. J. WALSH, care Fayette R. Plumb, Bridesburg, Philadelphia.
MR. ALBERT G. PETERKIN, care Benzol Products Company, Frankford, Philadelphia.

NON-RESIDENT.

MR. GUSTAV DIETZ, 317 East Thirty-fourth St., New York City.
MAJOR GEORGE OWEN SQUIER, Signal Corps, U. S. Army, Washington, D. C.
MR. JOHN STONE STONE, 31 State St., Boston, Mass.
MR. ANGUS KENNETH MILLER, 85 Clinton St., Brooklyn, N. Y.
MR. ROBERT ROWELL ABBOTT, Peerless Motor Car Company, Cleveland, Ohio.

ASSOCIATE.

MR. CHARLES WILLIAM SAXE, Newport Water Works, Newport, R. I.

Changes of Address.

MR. GANO DUNN, 117 West Fifty-eighth St., New York City.
MR. E. E. KELLER, Penobscot Building, Detroit, Mich.
DR. MORTON G. LLOYD, 319 South Oak Park Ave., Oak Park, Ill.
MR. E. F. MASON, Pennsylvania Railroad, Altoona, Pa.
MR. SOMMERS N. SMITH, 1744 North Sixteenth St., Philadelphia, Pa.

NECROLOGY.

James Christie, 3d Vice-President of the Franklin Institute, passed away at his summer home in Atlantic City on August 24th, within a few days of the 71st anniversary of his birth. He was the son of Thomas H. and Elizabeth Holmes Christie, born August 28, 1840, at the homestead of the family near Ottawa, Canada, where his grandfather, a native of Scotland, had settled on emigrating to America. Such education as was afforded him by the public schools of his native place he supplemented by reading and by acquiring a larger knowledge of French than he had learned in the *patois* of his French-Canadian comrades. His favorite theme from boyhood was Mechanics, and, having trained himself to proficiency in mechanical drawing, he went to Detroit in his 18th year and found employment as draughtsman in a machine shop. Not content with the training of the draughting-room, he widened his experience by working at intervals as journeyman machinist, and by the time he was twenty-three he had already demonstrated his fitness and efficiency in his chosen calling. He was employed in the extension of the Iron Mountain Railroad in Missouri, but, this enterprise becoming stalled by the progress of the Civil War, he found an opening for his talents in the then already widely reputed iron works of the I. P. Morris Company, of Port Richmond, Philadelphia. Here he met a number of men with whom he afterwards became associated in the Franklin Institute, including his subsequent fellow-member of the Committee on Science and Arts, the late John W. Cooper; his venerable predecessor in the vice-presidency of the Institute, the late Washington Jones, and his colleague in the City Councils of Philadelphia, the late John Hartman.

His four years' service at the I. P. Morris Iron Works was interrupted by his response to the call of his adopted country for volunteers to stem the tide of the Confederate invasion of Pennsylvania in 1863, but the decisive result of that campaign soon permitted him to resume the work for which his talents so specially fitted him.

In 1865 Mr. Christie joined with Henry Lewis Butler, of Phillipsburg, N. J., in a partnership to carry on a foundry and machine works in that city. In the succeeding years we find him taking an active part in the public affairs of Phillipsburg, first as a member of the Town Council and later, in 1874, as Mayor of the city. His record in that capacity, like that of his more recent political activity in Philadelphia, is that of a reformer in politics and an unselfish administrator of public as well as of private trusts.

In 1876, having become widely reputed as a builder of iron bridges and as an industrial organizer, Mr. Christie was called to aid in the reorganization and upbuilding of the Pencoyd Iron Works of A. and P. Roberts & Company, of Philadelphia. Here his abilities found full sway. He took upon himself, as chief mechanical engineer of the works, to increase the efficiency of the plant by what has now come to be known as "scientific management." He reorganized the working forces of the establishment

JAMES CHRISTIE
1840–1911

to the end in view, introduced new methods of procedure whereby waste of time was avoided, and added new appliances, many of them devised by himself, whereby the output was at once lessened in cost and improved in quality. The success of Mr. Christie's methods in this undertaking became manifest in the rapid growth of the Pencoyd Works from that of a concern of minor standing to that of one of the most important factors in the bridge-building industry of the country. When, in 1899, that industry was further reorganized by the combination known as the American Bridge Company, of which the Pencoyd Works became a part, James Christie was retained as chief mechanical engineer and was given the task of laying out the great bridge-building plant located at Ambridge, Pa., on the Ohio River, the largest establishment of the kind now extant. His connection with the American Bridge Company continued until 1905, when he resigned and practically retired from active work.

In the midst of his successful prosecution of the art of bridge building James Christie did not omit to contribute largely to its science as well. Among these contributions may be mentioned particularly his treatise entitled "Experiments on the Strength of Wrought Iron Struts," a record of his researches in this direction at the Pencoyd Works. This paper, published in 1884, centred the attention of the engineering world as an exhaustive treatise on a subject of prime technical importance, and remains to this day a standard exposition of its subject matter. For this work the American Society of Civil Engineers awarded Mr. Christie the Norman medal.

While never ceasing his efforts to promote the interests of his profession, James Christie extended his activities into the larger field of general science as well. He became a member of the Franklin Institute in 1885, and from that time to his death he took a prominent part in its proceedings. He was to the last a member of the Committee on Science and Arts, its chairman in 1897, and his work in that connection is embodied in numerous reports of that committee published in the JOURNAL of the Institute. In addition to his work on that committee, Mr. Christie gave unremitting service to the Institute as a member of its Board of Managers, and as chairman of the committee charged with arranging the programme of its meetings. He was also a member of the Publication Committee, and served at intervals on each of the other standing committees of the Institute. In 1909, after the death of the late Secretary of the Institute, Dr. Wahl, Mr. Christie voluntarily took up the duties of that office and gave valuable service in that capacity. In 1911 he was elected Vice-President of the Institute in succession to the late Washington Jones, and so continued his usefulness to the last.

Besides his activities at the Institute, Mr. Christie took a leading part in the work of the Engineers' Club of Philadelphia, of which he was one of the earliest as well as one of the most ardent members. He was accorded the unusual honor of being twice chosen as president of that organization, and occupied that office until the time of his death. He was a Fellow of the American Association for the Advancement of Science, a member of the American Philosophical Society, of the American Society of Civil Engineers, of the American Society of Mechanical Engineers, and of the G. A. R.

In the midst of his multifarious activities James Christie yet found time to give unselfish service to the cause of communal advancement. Besides serving as member of Select Council of Philadelphia from 1907 to 1910, as one of the few who gained election on an issue of municipal reform, he took an earnest part in the educational activities of his section of the city. He was also for a time a director of one of the local street railway lines.

James Christie was a most genial example of that not always genial genus, the "self-made man." His characteristics of forceful ability and innate modesty, of deep earnestness and refined good humor, of high ideals and practical common sense, combined to make him what he was, a leader in his profession and an efficient and welcome co-worker in all the other fields of his activity.

LOUIS E. LEVY,
JAMES M. DODGE,
E. H. SANBORN.

Mr. Cyrus Chambers, Jr., Overbrook, Pa., was born at Kennett Square, Pa., December 6, 1833, and died, after a brief illness, on July 9, 1911.

His inclination toward mechanical pursuits manifested itself early in life, and the many machines and other devices which he made while a boy attracted considerable attention.

A miniature high-pressure steam engine, composed of 150 pieces of gold and silver and weighing when completed less than half an ounce, was one of his achievements.

His earliest invention of note was a paper-folding machine for books and newspapers. This was put into commercial use in 1857 and led to the establishment of the firm known as Chambers Brothers & Company.

In 1861 Mr. Chambers manufactured and put upon the market a sewing machine which became quite popular, large numbers being sold in a short time.

He devoted much attention to the study of brickmaking, and the Chambers brickmaking machine has been in successful use for more than half a century. The first machine of its kind was erected at Pea Shore, New Jersey, early in the sixties, and turned out about forty bricks per minute. After forty-five years the machine is still in operation, and with the later improvements which have been added from time to time it now produces about forty thousand bricks per day.

Mr. Chambers became a member of the Institute in 1856, and for a number of years was active on various committees. He served several terms on the Committee on Science and the Arts, from 1876 to 1890 was a member of the Board of Managers, and during the past fifteen years he had been one of the Trustees.

Major James C. Brooks, whose death occurred at Philadelphia on July 18, 1911, was born in New Albany, Ind., in 1843.

At the outbreak of the Civil War he entered the Union Army, and served with distinction, attaining the rank of Major.

After the close of the war, Major Brooks entered mercantile life, and eventually became associated with the firm of William Sellers & Company, of Philadelphia, machine tool manufacturers. Later he became a partner in the firm.

In the year 1887 he was asked to take the office of President of the Southwark Foundry and Machine Company, of Philadelphia, builders of engines and other heavy machinery, which position he held until the time of his death.

Under his guidance this company became a leader in the class of work it was doing in the United States. The plant was enlarged, and the business grew to such proportions that in the course of the next five years its capacity was more than doubled, with the establishment of a name and reputation that was highly regarded not only in the United States but in Great Britain and the Continent of Europe.

He had studied with much care the early development of the iron and steel industry, and through his persistent efforts the Southwark Company designed an improved type of blast furnace blowing engine that has been used with great success throughout the civilized world where such industry is carried on.

Major Brooks was a director of the Franklin National Bank, the National Bank of the Northern Liberties, the Philadelphia Trust, Safe Deposit and Insurance Company, and a manager of the Western Saving Fund Society.

He became a member of the Franklin Institute in 1868, and during the past six years served as one of its Trustees.

Alexander Krumbhaar, who died at his residence in Wynnewood, Pa., on August 14, 1911, was the son of Lewis and Sophia Ramsay Krumbhaar, and was born in Philadelphia on July 27, 1842. His father was a member of the Franklin Institute, having joined in 1848. His son Alexander became a member in 1868, and was elected to the Board of Managers in 1898, and up to the time of his death served the best interests of the Institute by his intelligent and conscientious work. For many years he acted as chairman of the Membership Committee, and in connection with the duties of that office established many of the friendly relations existing to-day with some of the large manufacturing establishments in the city.

At the breaking out of the Civil War, in 1861, Alexander Krumbhaar, although a lad of but eighteen years of age, was chosen as an assistant by Major G. D. Ramsay, who was commandant of the Washington Arsenal. His thoroughness and ability were soon recognized, and the Military Storekeeper at the arsenal practically relied upon him for the delivery of arms, accoutrements, and ammunition for the infantry, cavalry, and artillery of the regular and volunteer army, and thus he practically outfitted the then Army of the Potomac with such supplies.

On the promotion of Major Ramsay to be Chief of Ordnance and to the title of Major-General, he was succeeded by Major Stephen V. Benet, who urged Alexander Krumbhaar to remain with him at the Washington Arsenal, and subsequently, in 1864, when Major Benet was ordered to New York in connection with ordnance duty, he applied for and took him as his chief assistant. He was succeeded in the New York work by Major Benton, of the Ordnance Corps, with whom Alexander Krumbhaar remained. Colonel Benet, shortly after taking command of Frankford Arsenal, applied for Alexander Krumbhaar as his assistant, and, much against the wishes of Major Benton, the transfer was made. Colonel Benet remained at the Frankford Arsenal for several years, being ably assisted in his work by Alexander Krumbhaar, and shortly after his leaving to become General and Chief of the Ordnance Corps, with headquarters at Washington, Alexander Krumbhaar resigned and returned to private life and went into the business of manufacturing hand-made files. He continued this business for a number of years, eventually retiring to become interested in corporation work. His early military association prompted him to join the National Guards of Pennsylvania, and on September 9, 1878, he received his appointment as Major and Ordnance Officer of the First Brigade. He was reappointed on September 10, 1883, and on October 27th of the same year was promoted to Lieutenant-Colonel, with the duties of Assistant Adjutant-General. On June 3, 1887, he was appointed on the General Headquarters staff, still retaining the duties of Assistant Adjutant-General, and reappointed on February 2, 1891. In the early part of 1892 he filled the duties of Active Adjutant-General, and on February 15, 1895, was placed on the retired list.

General George R. Snowden, now on the retired list, but for many years in command of the First Brigade, eulogized Alexander Krumbhaar as follows: "His death is a great loss to me, for I highly esteemed him as a man of character and ability, worth and integrity. When together so long in the military service I relied constantly and with a firm assurance, gained by experience and observation, on his knowledge, capacity, energy, attention, and, in fact, all the qualities which go to make up worth and distinction. He was one of the most useful and valuable officers ever in the National Guard, a fact, it is a satisfaction to know, generally, I may say universally, recognized. He was frank, open, sincere, not afraid or, indeed, reluctant to express his opinion—and he always had one, and that clear and intelligent—on any subject brought to his attention."

Alexander Krumbhaar was of strong, marked personality and of the highest integrity, having a high sense of justice and fairness for his fellowmen. His sterling character was readily recognized by those with whom he came in contact. This, combined with a kindly and courteous disposition, endeared him to all who knew him.

LAWRENCE T. PAUL,
A. C. HARRISON,
COLEMAN SELLERS, JR.

Mr. J. Walter Ruddach, Jenkintown, Pa.
Mr. Charles J. Hughes, Jr.

LIBRARY NOTES.

Purchases.

BUNNELL, S. H.—Cost-keeping for Manufacturing Plants.
ARRHENIUS, S.—Theorien der chemie.
ARRHENIUS, S.—Immunochemie.
ARRHENIUS, S.—Das Werden der Welten.
ARRHENIUS, S.—Die Vorstellung vom Weltgebäude.
BUCKLEY, R. B.—The Design of Channels for Irrigation.
SCHNEIDER, N. H.—Electric Light for the Farm.
NIELSEN, T.—Calculation of Columns.
ZAHN, A. F.—Aerial Navigation.
EVANS, H. A.—Cost-keeping and Scientific Management.
LOUIS, H.—Metallurgy of Tin.

Gifts.

U. S. Commissioner of Labor, 24th Annual Report, 1909, Volume 2. Washington, 1911. (From the Commerce and Labor Department.)

U. S. Senate Committee on Manufactures, Hearings on Foods Held in Cold Storage, 1911. Washington, 1911. (From the U. S. Senate.)

Jefferson Physical Laboratory, Contributions, Volume 8, 1910. Cambridge, Mass., n. d. (From the Laboratory.)

Meteorological Committee, London, 6th Annual Report, for year ending March, 1911. London, 1911. (From the Meteorological Office.)

Royal Astronomical Society, General Index to the Monthly Notices, Volumes 53–70, 1892–1910. London, 1911. (From the Society.)

Great Britain, Labour Department, Report on Changes in Rates of Wages and Hours of Labor. London, 1911. (From the Department.)

Institution of Civil Engineers, Minutes of Proceedings. Name Index, 1894–1907. London, 1910. (From the Institution.)

Australia Commonwealth, Official Year Book, 1911. Melbourne, n. d. (From the Commonwealth Statistician.)

Smithsonian Contributions to Knowledge, vol. 27, No. 3, "Langley Memoir on Mechanical Flight." Washington, D. C., 1911. (From the Smithsonian Institution.)

Victoria, Annual Report of the Secretary for Mines for the Year 1910. Melbourne, 1911. (From the Department of Mines.)

American Society for Testing Materials, Year Book. Philadelphia, 1911. (From the Society.)

Toronto Bureau of Mines, Annual Report, vol. 20. Toronto, 1911. (From the Bureau.)

New Zealand Institute, Transactions and Proceedings, vol. 43, 1910. Wellington, 1911. (From the Institute.)

Great Britain, Labour Department, Report on Strikes and Lock-outs and on Conciliation and Arbitration Boards in 1910. London, 1911. (From the Labour Department.)

Pennsylvania State Railroad Commission. In the matter of the complaints against the Philadelphia Rapid Transit Company. Report to the Commission by Ford, Bacon and Davis. Two volumes. 1911. (From R. D. Jenks, Esq.)

Chicago Mayor's Annual Message and 35th Annual Report of the Department of Public Works for 1910. Chicago, n. d. (From the Department.)

Pennsylvania Department of Agriculture, 15th Annual Report, 1909. Harrisburg, 1910. (From the State Library.)

Pennsylvania Department of Forestry, Report for the years 1908–09. Harrisburg, 1910. (From the State Library.)

Pennsylvania Department of Mines, Report for 1909. Part I, Anthracite. Harrisburg, 1910. (From the State Library.)

Pennsylvania Department of Internal Affairs, Annual Report for 1909–1910. Part 4, Rail-Roads, Canals, Telegraphs and Telephones. Harrisburg, 1911. (From the State Library.)

Pennsylvania State Railroad Commission, Report for 1910. Harrisburg, 1911. (From the State Library.)

Pennsylvania Department of Fisheries, Report for 1909, 1910. Harrisburg, 1911. (From the State Library.)

Thompson, Slason. Railway Library, 1910. Chicago, 1911. (From the Editor.)

New South Wales, Vital Statistics for 1910. Sydney, 1911. (From the Government Statistician.)

BOOK NOTICES.

Carnegie Institution of Washington, Publications. No. 54. Bailey Willis, Charles D. Walcott, and others. "Research in China." In three volumes and atlas.

Vol. 1 in two parts $8.00
  Part I. Descriptive Geology; by Bailey Willis, Eliot Blackwelder, and R. H. Sargent. Quarto, pages xiv + 353 + xvi, plates I–LI, 65 text figures.
  Part II. Petrography and Zoology; by Eliot Blackwelder. Syllabary for Transcription of Chinese Sounds; by Friedrich Hirth. Quarto, pages vi + 355–528 + xvii–xxiv, plates LII–LXII (including 6 plates of birds colored to life).
Atlas. By Bailey Willis, Eliot Blackwelder, and R. H. Sargent. Folio. 42 maps and 21 other illustrations..............................$7.00
Vol. 2. Systematic Geology. By Bailey Willis. Quarto, v + 133 + v pages, 8 plates $2.00
Vol. 3. Paleontology. By Charles D. Walcott, Stuart Weller, and George H. Girty. Quarto ....In preparation

Volume I, Part I, contains observations relating to the geology of northeastern, northern, and central China (Shan-tung, Chi-li, Shan-si, and Shen-si). The treatment is primarily by districts, and under each district the terranes observed are described in order from older to younger. The nature and succession of strata, the fossils, and the structure of each terrane are discussed. The terranes observed may be enumerated as follows: Pre-Cambrian, Cambrian, Ordovician, Devono-Silurian (in central China only), Carboniferous, Permian (?), Jurassic, and Quaternary. The principal contributors to knowledge relate to the Pre-Cambrian, the stratigraphy and fossils of the Cambrian, and the history of the Quaternary. The last named comprises an analysis of the mountain forms in terms of uplift and erosion and a discussion of the loess. A unique feature is the account of an early Cambrian tillite or glacial till, which underlies the Cambrian limestone of the Yang-tzi valley. The volume is profusely illustrated with photographs of the scenery of the mountain districts of Chi-li, Shan-si (the land of the loess), and Shen-si.

The atlas contains two route maps, 20 topographic maps, and 20 identical geologic maps. The topographic maps represent the features along and adjacent to the route on a scale of 1:125000, with 100-foot contours. They are based on plane-table surveys and the forms of the land were stretched expressively in contours on the spot.

Vol. I, Part II, includes three special reports which are subsidiary to the general treatment of the geological observations in Part I of the same volume.

The first and largest section contains a description of the varieties of igneous, metamorphic, and sedimentary rocks collected by the expedition in China. All of these specimens come from northern China, the majority of them being from Shan-tung, western Chi-li, eastern Shan-si, and southern Shen-si. The collection comprises typical representatives of the geological systems from Archean to Mesozoic. Of special importance is the description and interpretation of the varied oolitic and conglomeratic limestones, found in the Cambrian terrane.

The second section, dealing with zoological observations of the party, includes an annotated list of the amphibians, reptiles, and birds observed. About 130 species of birds are noted, and of these six of the least known are illustrated by beautiful colored plates.

The last section contains a syllabary of Chinese sounds, prepared by Professor Hirth, of Columbia University. The orthography recommended by the author is compared in tabular arrangement with that of Williams and Wade, and all are referred to the corresponding Chinese ideographs.

Volume II treats of the same material as Volume I, but from the standpoint of systematic continental history. Repetition has been avoided so far as is consistent with the general subject. The subject-matter of this volume is classified primarily according to geologic eras of periods, and secondarily by broad areas, of which China proper is the central region. Each chapter treats of the geographic condition of southeastern Asia during a particular age, and the successive chapters trace the sequence of changes from age to age. Only the great events of continental history are distinguishable on the basis of existing knowledge, but they suffice to show that the present continent is an aggregation of land masses which, from time to time, have been forced into union with one another. This study of Asia has been carried on with comparative studies of North America and Europe, and has led to theoretical views regarding continental structure and development which have a broad application. They are briefly stated in a closing chapter.

PUBLICATIONS RECEIVED.

Direct and Alternating Current Manual, with Directions for Testing and a Discussion of the Theory of Electrical Apparatus. By Frederick Bedell, Ph.D., assisted by Clarence A. Pierce, Ph.D. 360 pages, illustrations, 8vo. New York, D. Van Nostrand Co., 1911. Price, $2 net.

A pocket medical dictionary, giving the pronunciation and definition of the principal words used in medicine and the collateral sciences, including very complete tables of the arteries, muscles, nerves, bacteria, bacilli, micrococci, spirilla and thermometric scales, ... By George M. Gould, A.M., M.D. Sixth edition, revised and enlarged. 1005 pages, 16mo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, in leather, $1 net.

The Technical Analysis of Brass and the Non-ferrous Alloys. By William Benham Price and Richard K. Meade. First edition. 267 pages, illustrations, 12mo. New York, John Wiley & Sons, 1911. Price, $2 net.

Electro-analysis. By Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. Fifth edition, revised and enlarged. 332 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, in leather, $2.50 net.

Essai sur une méthode de comptabilité des chemins de fer par Gustave Pereire. Premiere partie. 132 pages, quarto. Paris, Gauthier-Villars, 1911.

University of Illinois Bulletin. Water Survey Series No. 8. Chemical and Biological Survey of the Waters of Illinois. Report for 1909 and 1910. Edward Bartow, Director. 148 pages, illustrations, maps, 8vo. Urbana, University, 1911.

Ontario Bureau of Mines. Twentieth annual report, 1911, being volume xx, part 1. 301 pages, illustrations, plates, maps, 8vo. Toronto, King's printer, 1911.

Instructions for Experiments in Laboratory for Testing Materials, Purdue University. By W. Kendrick Hatt, professor of civil engineering and director of laboratory for testing materials, and H. H. Schofield, assistant professor in laboratory for testing materials. 72 pages, illustrations, 8vo. Lafayette, Ind. Authors, 1911.

U. S. Department of Agriculture, Forest Service, Bulletin 99. Use of Commercial Woods of the United States: II. Pines. By William L. Hall, assistant forester, and Hu Maxwell, expert. 96 pages, 8vo. Washington, Government Printing Office, 1911.

Multiplex Telephony and Telegraphy by Means of Electric Waves Guided by Wires. By George O. Squier. A paper presented at the 28th

Annual Convention of the American Institute of Electrical Engineers, Chicago, Ill., June 28, 1911. 48 pages, illustrations, 8vo. Reprinted from the Proceedings for May, 1911.

American Mining Congress, October 24–28. Announcement of meeting, programme and speakers. 30 pages, illustrations, 8vo. Chicago, 1911.

National Association of Cotton Manufacturers. Fourteen pamphlets, advance copies of papers presented at the semi-annual meeting held at Manchester, Vt., September 27–30, 1911. Boston, Association, 1911.

North Carolina Geological and Economic Survey. Economic Paper No. 22. Forest fires and their prevention, including forest fires in North Carolina during 1910. By J. S. Holmes, forester. 48 pages, 8vo. Raleigh, State printers, 1911.

U. S. Geological Survey. Water Supply Paper 239. The quality of the surface waters of Illinois. By W. D. Collins. Prepared in coöperation with the Illinois State Water Survey, the Illinois State Geological Survey, and the Engineering Experiment Station of the University of Illinois. 94 pages, plates, maps, 8vo. Washington, Government Printing Office, 1910.

Pennsylvania State College Bulletin. Winter Courses in Agriculture. 15 pages, illustrations, 8vo. State College, 1911.

U. S. Bureau of Standards. Circular No. 8. Testing of Thermometers. Second edition, revised and enlarged. 52 pages, illustrations, 8vo. Reprint No. 149. On the Constancy of the Sulphur Boiling Point. By C. W. Waidner, physicist, and G. K. Burgess, associate physicist. 4 pages, 8vo. Washington, Government, 1910–11.

State Employers' Liability (or Workmen's Compensation) Insurance. By Edson S. Lott, president, United States Casualty Company, New York. Read before the Liability Insurance Association at its annual meeting, Hotel Astor, New York, October 19, 1911. 15 pages, 8vo.

CURRENT TOPICS

The Properties of Mesothorium. O. Hahn. (*Chem. Zeit.,* xxxv, 845.)—Mesothorium is the first disintegration product of thorium. It is composed of two constituents, mesothorium I and mesothorium II, which latter gives off β- and γ- rays. By gradual disintegration mesothorium forms, first radio-thorium, then thorium X emanations and thorium A-B-C-D. Radio-thorium exists in equilibrium with the last four and emits α-, β- and γ-rays. The disintegration of mesothorium occurs with an increase of radioactivity. This increase, starting with pure mesothorium, would last about 3.2 years and would be followed by a slow decrease for 10 years, and a value half that of the original mesothorium is reached in 5.5 years. Technically-prepared mesothorium contains about 25 per cent. of radium, which greatly extends the period of decrease. It requires 1800 years to reduce the radio-activity of radium to one-half, and assuming that radio-activity is inversely proportional to the rate of disintegration, the radio-activity of mesothorium must be 300 times that of an equal weight of radium. As technically-prepared mesothorium has a radio-activity equal to that of pure radium bromide, and as it contains 25 per cent. of radium bromide, the remainder must consist of 0.25 per cent. of mesothorium and 74.75 per cent. of inactive substance. The author succeeded in separating the inactive substance, and obtaining a product whose radio-activity was nearly four times as great as that of an equal weight of pure radium bromide, but attempts at the further separation of the mesothorium and radium were unsuccessful, as the chemical properties of the two substances are similar. Pure mesothorium emits only β- and γ-rays, so that the α-rays in technically-prepared mesothorium are due to the presence of radium.

A New Electro-galvanizing Solution. E. F. Kern's Patent. (*Brass World,* vii, 9, 331.)—The ingredients are:

Water	1 gallon
Zinc chloride	1 pound
Sodium-aluminum chloride	5 ounces
Sodium chloride	4 ounces
Grape sugar	5 ounces

Requires a very high-current density with a very low voltage. With a current density of 20 ampères per square foot, only 0.55 to 0.66 voltage is required. A dense adherent deposit, free from zinc salt or zinc oxide, was obtained. A temperature of 100° F. is advisable.

Melting Metals with High-pressure Gas. U. S. CONSUL ALBERT HALSTEAD. (*Brass World,* vii, 9, 312.)—The use of high-pressure gas for melting metals is attracting great interest in England. No air blast is necessary, so a *reducing* flame is obtained, without noise, and the loss by oxidation is greatly reduced. In brass melting the loss of zinc is only 75 per cent. of the loss in coke furnaces; and there is no loss of copper. Foundry aluminum is melted at a cost of $1.46 per ton in the Birmingham gas department.

The New Mechanics. EDWIN TARRISSE. (*Amer. Mach.,* xxxv, 363.)—As has been repeatedly pointed out in France, the contrast between the so-called "New Mechanics" and the old mechanics, based on Newton's laws of motion, offers some interesting features. The new conceptions of the science of motion are not easily presented to the lay mind because of their entire novelty. The modern idea is that a constant force acting upon a moving body does not impart equal velocity in each successive second, but that the accelerative effect decreases as the velocity of the body increases, and finally reaches a limit that it cannot pass. This limit is the velocity of light. In other words, the inertia of matter increases with its velocity of translation, and becomes infinite when the velocity is equal to that of light. Another form of statement is that the mass of a material body increases with its velocity of movement, and that there can be no motion swifter than that of light; that is, about 186,330 miles per second.

The Escape of Gas from Coal. H. C. PORTER AND F. K. OVITZ. (*U. S. Bureau of Mines Technical Paper* No. 2, 1.)—Laboratory experiments made with certain American bituminous and semi-bituminous coals from dangerous mines showed that these coals liberate methane not only during mining but also for a long period afterwards. Taking the volume of coal as unity, about ¼ volume of methane escaped during crushing and ½ to 1½ volumes on continued exposure to air. The escape of methane was rapid at first, but ceased after 3 to 18 months. The reduction of the calorific value of the coal due to the loss of methane was very small. Such coals absorbed oxygen over a prolonged period at varying rates, without an equivalent formation of carbon-dioxide. The well-known influence of atmospheric pressure on the liberation of inflammable gases in mines is probably due to the pressure of reservoirs of these gases in the stratified rocks, and not to the presence of gases in the substance of the coal itself.

The Constitution of Water. J. DUCLAUX. (*Mon. Scient.,* lxxv, 555.)—According to Röntgen's hypothesis, water consists of molecules of ice (as a dissolved body); that is to say, the water is polymerized for one part, and the other part is an ideal liquid, which cannot exist in the pure state without also partly polymerizing, which Sutherland has named *hydrol*, and which is formed of simpler molecules than those of ice. Therefore, water is a solution of ice in hydrol. In considering this hypothesis it must be admitted that the molecule of ice is $(H_2O)_3$. J. Duclaux studied this question by new methods and arrived at different conclusions. He found that ice polymerizes approximately as $(H_2O)_9$, M. Wt. 162, to $(H_2O)_{12}$, M. Wt. 216. These numbers were obtained by the study of the variation of the expansion of water with the pressure; if the variations of the compressibility with the temperature are calculated, the numbers found for the molecule of ice agree with the formulas $(H_2O)_6$, M. Wt. 108, and $(H_2O)_{23}$, M. Wt. 414. By combining the formula of expansion given by Röntgen for water:

$$V = a + bT + cT^2 + dT^3 \dots + KT^{-\delta} \frac{\alpha}{eT^3} + \frac{\beta}{T^2} + \frac{\gamma}{T} + \xi T,$$

the parabolic terms representing the expansion of hydrol, and the exponential terms the excess of the volume of ice dissolved over that which the hydrol would give in de-polymerizing alone, with those which the study of the specific heat gives, another method of determining the polymerization of ice is reached. This gives the molecule of ice as $(H_2O)_{12}$, M. Wt. 216.

Locomotive Cylinder Castings. ANON. (*Amer. Mach.*, xxxv, 320.)—According to *Railway and Locomotive Engineering*, the composition of cast iron for locomotive cylinder castings has been carefully estimated by mechanical engineers as follows: Graphitic carbon, 2.75 to 3.25 per cent.; silicon, 1.25 to 1.30; phosphorus, 0.50 to 0.80; combined carbon, 0.50 to 0.70; manganese, 0.30 to 0.60; and sulphur, 0.06 to 0.10 per cent. The presence of sulphur in an excessive degree is said to be one of the serious evils to be particularly guarded against in the selection of cast iron, while the proper mixture of silicon is also of the greatest importance.

Tests of Lubricating Grease. G. W. LEWIS. (*Amer. Mach.*, xxxv, 356.)—This is a valuable article for all users of lubricants. In brief it may be summarized as showing that the results of tests on a large number of greases give the coefficients of friction and rise in temperature of the bearings. There are also given several simple tests that can be made by the user to determine the character of the grease under consideration, *e.g.*, tests for acids, alkalies, volatile matter, filling, water and propensity to gum.

Loss in Coal Due to Storage. A. BEMENT. (*Chem. Eng.*, xii, 9.)—In experiments to find (*a*) change in heating power, (*b*) change in weight, (*c*) tendency to disintegrate by slacking, in certain Illinois coal when in storage, Springfield coal showed a loss in heating power of 0.93 per cent., loss in weight of 1.15 per cent.; central seam coal, 1.85 per cent. loss in heating power and 2.29 per cent. loss in weight; southern seam coal, 0.38 per cent. loss in heat-value and 0.11 per cent. gain in weight. Southern seam coal retained 87.84 per cent. in lump form; Springfield coal 35.49 per cent., and central seam coal 18.36 per cent. Stored under water, central lost 0.44 per cent. in heat-value and 0.35 per cent. in weight; southern gained 0.02 per cent. in heat-value and lost 0.81 per cent. in weight. All tests were for a period of one year.

Large Crane. ANON. (*Amer. Mach.*, xxxv, 210.)—The largest crane in the world has been recently erected at Govan, near Glasgow, on the river Clyde, for the Fairfield ship-yards. On slow gear the crane can elevate 200 tons extended 75 feet along the jib, and on quick gear it can carry a load of 100 tons at 133 feet. The stability of the crane is maintained by four large tubes, 15 feet in diameter at their bases, filled with concrete, and sunk 74 feet below ground.

Absorption Spectrum of Iodine and Bromine Vapor at High Temperatures. E. J. EVANS. (*Astro. Physic. Journal*, xxxii, 1 and 291.)—Iodine vapor at different pressures was heated in a quartz tube to various temperatures up to about 1300° C. and its absorption spectrum was studied by passing through it light from a carbon arc which was examined by means of a concave grating spectroscope of 1 mm. focus. The temperature at which the absorption spectrum vanishes increases with the increase of pressure. The degree of dissociation of the iodine vapor is high at these temperatures, and it is therefore assumed that the cause of the disappearance is that the monatomic molecules show no absorption for the visual spectrum, and that absorption is due to the diatomic molecules. The absorption spectrum of bromine vapor disappears at high temperatures, and the temperature of disappearance is increased by increase of pressure. The disappearance of the absorption lines is closely connected with the dissociation of the diatomic molecules, and can be explained on the hypothesis that the monatomic molecules produced by dissociation give no absorption spectrum within the limits λ 3500 to λ 6800.

Phellandrene Process for Extracting Copper. ANON. (*Chemist and Drug.*, July 29, 1911.)—This process was first used at Broken Hill, in New South Wales, but its use is now widely extended. The crushed and ground ore is mixed with water to a cream and 4 pounds of eucalyptus oil, containing phellandrene, are added to each ton of ore; the copper is collected by the phellandrene and this floats to the surface of the magma. The oil is then removed by distillation. The oils of eucalyptus containing phellandrene appear to be the only oils suitable for the purpose, and their use for the extraction of copper has considerably enhanced their value. Inquiries for oils yielding phellandrene are now being made all over the Eastern States of Australia, and an increased production of these oils has resulted. The labor conditions are a great drawback to the eucalyptus oil industry as they are to the other industries.

The Kinetic Theory of Gases and the Realization of a Material Radiation of Thermal Origin. L. DUNOYER. (*Comptes Rendus,* clii, 592.)—The following experiment appears to afford evidence of the kinetic movements of molecules in a gas. A cylindrical tube is divided into three compartments by partitions perpendicular to the axis of the tube; these partitions are pierced by a small hole in their centres, forming diaphragms. The tube is fixed in a vertical position and a substance, non-volatile at the ordinary temperature, such as sodium, is placed in the lowest compartment, and then the tube is exhausted. The lowest portion is heated till the sodium vaporizes. The molecules of the vapor move in all directions in the lowest compartment with a mean velocity dependent on the temperature applied. Some of them traverse the lowest diaphragm; the majority strike the walls of the tube or the lower surface of the upper diaphragm, and deposit there. Some, however, pass through the hole in the second diaphragm. Among these molecules very few will collide, because their velocities are almost all in parallel directions, and since foreign gases are absent or negligible, these molecules continue on their straight course with a mean velocity of the order of 550 metres per second, if the sodium was heated to 400° C., until they strike the end of the tube. If an obstacle is in their path, a shadow will be formed or even an umbra and penumbra. No deposit is formed on the side walls of the upper compartment. This experiment appears to demonstrate the rectilineal propagation of something material; and further that this is not a mere turbulent jet of gas, but the propagation of particles in parallel straight lines.

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THE VAPOR PRESSURES OF LIQUID MIXTURES AND FRACTIONAL DISTILLATION.

BY

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THE partial and total vapor pressures of mixtures figure in two important chapters of physical chemistry, *viz.,* the theory of solutions and the theory of fractional distillation. The work described in this communication was carried out mainly in view of the needs of the theory of distillation.

Partial pressures cannot be directly measured as such. They are calculated from the molecular composition of a given vapor on the assumption that the pressures are proportional to the relative numbers of molecules. Hence, all methods of "measuring partial pressures" really consist in determining the composition of vapors in equilibrium with liquid mixtures.

The principal method employed in the past[1] consisted in distilling off a small amount from a large quantity of a given mixture and determining the composition of the distillate. The assumption involved, *viz.*, that the composition of the vapor does not vary during the distillation, can be strictly true only

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[1] See especially Zawidzki, *Z. physik. Chem.*, 35, 129 (1901).

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if the amount of distillate is infinitely small by comparison with the mother liquid. In practice one cubic centimetre is distilled off from about 100 cc. In some cases the removal of such a fraction is accompanied by appreciable changes in the vapor composition during distillation; but a graver source of inaccuracy lies in the difficulty of handling one cubic centimetre of a volatile organic mixture for analysis. Also, moisture is likely to accumulate in the first small fraction distilled off.

§1. *A Precise Method of Determining Partial Pressures.*

The writer, with collaborators, succeeded in devising a method which is apparently free from the errors and uncertainties attached to the older methods. The principle of the new method was first stated in a paper published jointly with A. B. Lamb and F. E. Breithut,[2] from which I quote: "If a binary liquid whose components are in the ratio $x/(1-x)$ is in equilibrium with a vapor containing the same components in the ratio p_1/p_2, then a saturated vapor of this composition will bubble through the liquid without producing, or itself undergoing, any change. If, on the other hand, a saturated vapor of any other composition, say p'_1/p'_2, is passed through the same liquid, the composition of the liquid will gradually change until the ratio of its components has become $x'/(1-x')$ corresponding to the composition p'_1/p'_2 of the vapor. After that the vapor may be passed through the liquid indefinitely without affecting its composition. Further, since condensation or evaporation involves a transfer of heat, and hence a rise or fall in temperature, it follows that if a saturated vapor of definite composition at the temperature T' be passed through a liquid mixture of the same components, the temperature T of the liquid will gradually approach T' as equilibrium is attained.

"In brief, then, if a mixed vapor of constant composition is passed through a liquid mixture of the same components, the composition and temperature of the liquid will steadily change until complete equilibrium, as regards both temperature and pressure, has been established. A stationary temperature will demonstrate the attainment of equilibrium. The vapor bubbling through the liquid may then be condensed in any desired quantity and analyzed. Identity of composition of two or more consecutive samples of the condensed vapor will be additional proof that perfect equilibrium had been established between liquid and vapor. On the other hand, the liquid can be drawn off and its composition determined by analysis."

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[2] *Journal of the American Chemical Society*, 31, 448 (1909).

The method was perfected in its experimental details by the writer in collaboration with C. W. Easley.[3] It was applied by them to the determination of the partial pressures of the following six binary mixtures: carbon tetrachloride and benzene, carbon disulphide and acetone, chloroform and acetone, ethylene chloride and benzene, carbon disulphide and carbon tetrachloride, and acetic acid and benzene.

Fig. 1 shows diagrammatically the apparatus used. Vessel *B* supplies the vapor of constant composition. The mixture originally placed in that vessel is heated electrically by means of a platinum wire not shown in the diagram. The composition of that liquid is kept closely constant by distilling into it enough of the more volatile component from *C* to maintain the boiling point in *B* constant as shown by a sensitive thermometer. The constant vapor from *B* enters *A*, the equilibrium chamber proper, through a side opening and tube reaching nearly to the bottom of *A*. The arbitrary mixture originally placed in *A* is changed in composition by the constant vapor bubbling through it, and consequently the boiling temperature in *A*, as shown by the sensitive thermometer *H*, rises or falls, as the case may be. The final attainment of a constant temperature indicates that equilibrium has been established between the liquid in *A* and the vapor bubbling through it. Then two or three large consecutive samples of the vapor, condensed and thoroughly cooled in *D* and *E*, are collected in the compartments of *F* for analysis. Finally, a sufficient sample is withdrawn for analysis from *A*, and thus the composition of the liquid and vapor in equilibrium with each other becomes known. During all our determinations the total pressure was kept constant at 760 millimetres with the aid of a 100-litre manostat tank. The binary mixtures were analyzed with the aid of an excellent Pulfrich refractometer.

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[3] *Journal of the American Chemical Society*, 31, 953 (1909); also *Z. physik. chem.*, 68, 641 (1910).

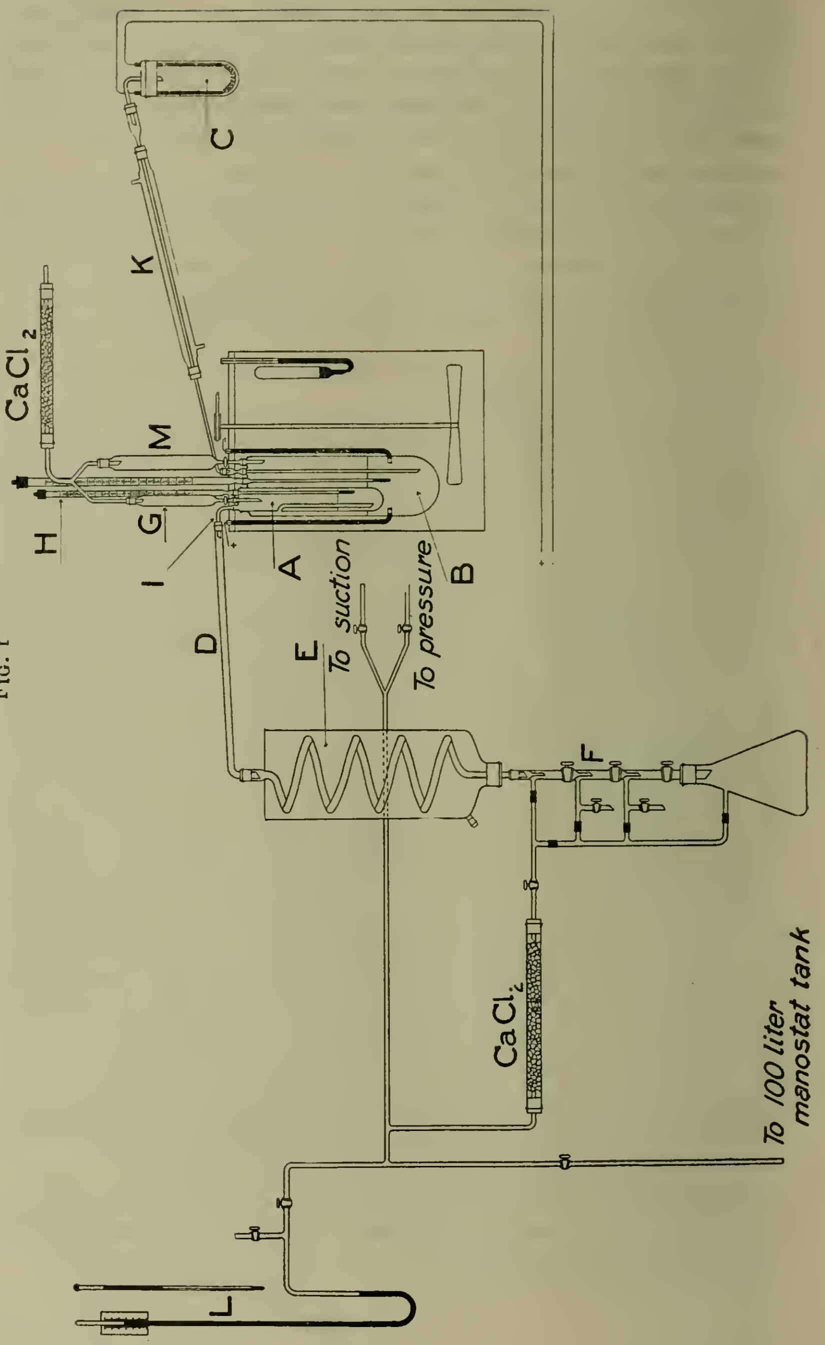
CaCl 2
M
K
C
H
G
I
A
B
D
E
To suction
To pressure
F
CaCl2
To 100 liter manostat tank
L

FIG. 1

The theoretical treatment of the results was founded on Kirchhoff's equation, which correlates the relative temperature gradient of partial pressures with the heat of dilution.[4] If the composition of mixtures is expressed, as done by Gibbs, in terms of molar fractions (molecular percentages divided by 100), the Kirchhoff equation assumes the form

$$\frac{\partial}{\partial T} \log \frac{P_1}{p_1} = \frac{1}{RT^2} \cdot Q - \frac{1-x}{RT^2} \cdot \frac{\partial Q}{\partial x},$$

where x is the molar fraction in the liquid phase of the component whose partial pressure in the vapor is p_1 and whose vapor pressure in the isolated state is P_1. The heat evolved in mixing the molar fractions x and $1-x$ of the two components is denoted by Q, and the absolute temperature by T.[5]

The right-hand member of the equation has RT^2 in the denominator. R, the gas constant, amounts in heat measure to nearly 2 (calories). And if the centigrade temperature is about 43°, the numerical value of T is 316, that of T^2 is about 100,000, and that of RT^2 is about 200,000. The relative change of $\frac{P_1}{p_1}$ with the temperature is consequently one 200,000th part of the heat of dilution. *And if the latter is moderate, as it is in the case of most organic mixtures, the change of* $\frac{P_1}{p_1}$ *with the temperature is negligibly small.*

The partial pressure of a mixture and its molar composition have been correlated by a semi-theoretical function introduced by Margules.[6] For the two components:

$$p_1 = P_1 x e^{\frac{\alpha_2}{2}(1-x)^2 + \frac{\alpha_3}{3}(1-x)^3 + \frac{\alpha_4}{4}(1-x)^4}$$

and

$$p_2 = P_2 (1-x) e^{\frac{\beta_2}{2}x^2 + \frac{\beta_3}{3}x^3 + \frac{\beta_4}{4}x^4}$$

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[4] *Poggendorff's Annalen*, 103, 200, and 104, 615 (1858).

[5] The above equation was given in our original communication in an imperfect form; but the conclusions there drawn are not affected by the correction.

[6] *Sitzungsbericht der Wiener Akademie*, 104, 1243 (1895).

Since, according to the Kirchhoff equation, the ratio $\frac{p}{P}$ is practically independent of the temperature, the coefficients α_2, α_3, α_4, β_2, β_3, and β_4 must likewise remain constant within moderate temperature ranges.

The pair of Margules functions must satisfy the well-known differential equation first deduced by Duhem,[7] and later rediscovered by Margules himself[8]:

$$d \log p_1 / d \log p_2 = d \log x / d \log (1-x).$$

This permits of eliminating one of the two sets of coefficients in the Margules functions, and then the functions may be readily combined into the following equation:

$$\log \frac{p_1(1-x)}{p_2 x} = \log \frac{P_1}{P_2} + \alpha_2 \left[(1-x) - \frac{1}{2} \right]$$

$$+ \frac{\alpha_3}{2} \left[(1-x)^2 - \frac{1}{3} \right] + \frac{\alpha_4}{3} \left[(1-x)^3 - \frac{1}{4} \right].$$

Since the α's are independent of temperature variations, this last equation will represent partial pressures measured either isothermally or isopiestically. Our own measurements, as before stated, were isopiestic.

The principle of the practical constancy of $\frac{P}{p}$ during moderate temperature changes is capable of a variety of useful applications. I should like to point out here one such application not mentioned in the original communication. Professor Morse and his collaborators, at Johns Hopkins University, have carried out a large number of direct determinations of osmotic pressure. One of the questions submitted by them to the test of experiment was whether osmotic pressure, like gas pressure, is proportional to the absolute temperature, and at one time experiment seemed to indicate that it was not. Now, osmotic pressure must obey the following thermodynamic equation:

$$\pi = \frac{1000\, RST}{M_0} \log \frac{P}{p}.$$

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[7] *Ann. de l'Ecole normale sup.* (3), 4, 9 (1887).

[8] *Sitzungsbericht der Wiener Akademie,* 104, II, 1243 (1895).

Here R is the gas constant, S is the density of the solution in which the osmotic pressure is π, M_0 is the molecular weight of the solvent in the gaseous state, and P and p are the vapor pressures of the solvent in the isolated state and in the solution, respectively. Dr. Morse has experimented mainly with solutions of cane sugar and within temperature ranges of only about 25 degrees. When sugar is dissolved in water the heat-change is so slight that in common experience one does not realize that there is any temperature change at all. Therefore, within Dr. Morse's temperature range, according to the principle explained above, the ratio $\frac{P}{p}$ ought to remain all but perfectly constant. Further, within ranges of 25 degrees the density of a sugar solution scarcely varies. The osmotic pressure equation therefore assumes the form

$$\pi = T \times \text{constant}.$$

In other words, the principle of the constancy of $\frac{P}{p}$ teaches that according to thermodynamics the osmotic pressure of a sugar solution *must* be very closely proportional to the absolute temperature. As a matter of fact, the most recent measurements at Johns Hopkins show that osmotic pressure obeys this temperature law within the slight experimental errors.

Returning to our partial pressure measurements, I will reproduce here, by way of an example, the results obtained in the case of carbon tetrachloride and benzene. In Table I the first column gives the observed boiling points; the second column gives the composition of the boiling mixtures in vessel A. The third and sixth columns (under p_1 and p_2 obs.) give the observed composition of the vapor expressed in terms of partial pressures, the sum being, as stated, 760 millimetres throughout. The fourth and seventh columns (under p_1 and p_2 calc.) give the corresponding partial pressures calculated by the equation:

$$\log \frac{p_1(1-x)}{p_2 x} = 0.097291 + 0.22284\left[(1-x) - \frac{1}{2}\right]$$

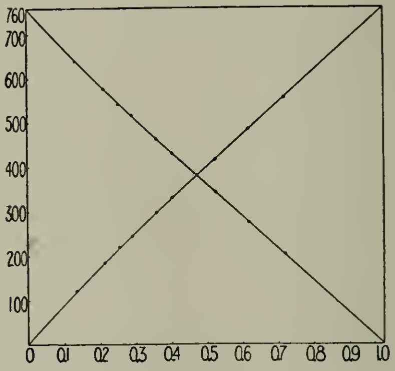
$$- 0.15975\left[(1-x)^2 - \frac{1}{3}\right] + 0.14883\left[(1-x)^3 - \frac{1}{4}\right].$$

Finally, the fifth and eighth columns give the percentage differences between the calculated and the observed values of p_1 and p_2, respectively. The agreement between calculation and experiment is all that can be desired. Fig. 2 reproduces the same set of results graphically.

TABLE I.

1 B. p. obs.	2 x CCl_4 in liquid	3 p_1 obs.	4 p_1 calc.	5 Diff. per cent.	6 p_2 obs.	7 p_2 calc.	8 Diff. per cent.
80.23°	0	0	0	0	760.0	760.0	0
79.36	0.1364	120.2	120.0	—0.03	639.8	640.0	+0.03
78.82	0.2157	183.9	184.1	+0.03	576.1	575.9	—0.03
78.62	0.2573	218.7	216.6	—0.28	541.3	543.4	+0.28
78.48	0.2944	244.1	245.1	+0.14	515.9	514.9	—0.14
78.15	0.3634	297.7	297.1	—0.08	462.3	462.9	+0.08
77.97	0.4057	330.6	328.5	—0.28	429.4	431.5	+0.28
77.57	0.5269	416.8	416.9	+0.01	343.2	343.1	—0.01
77.23	0.6202	485.0	484.1	—0.12	275.0	275.9	+0.12
77.07	0.7223	556.9	557.2	+0.04	203.1	202.8	—0.04
76.69	1.0000	760.0	760.0	0	0	0	0

FIG. 2.



§2. *A Rapid Laboratory Method of Measuring Partial Pressures.*

The method described in §1, while precise and undoubtedly reliable, is also laborious and requires some manipulative skill. In connection with distillation experiments, in the scientific as well as in the industrial laboratory, it left a need for a simpler and more rapid laboratory method.

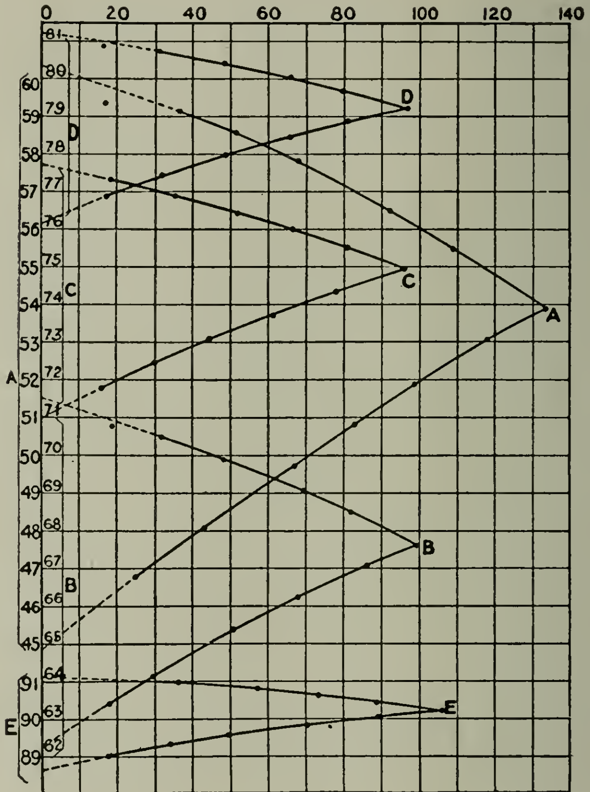
Such a method has recently been devised by C. W. Bacon and R. H. White in collaboration with the writer. It will be briefly described here for the first time, a detailed description and an exhaustive statement of results to be published before long.

Imagine, first, that from half a dozen samples of equal weight and identical composition we should distill off, say, respectively, 1, 2, 3, 4, 5 and 6 grammes, avoiding all reflux condensation, and analyze the six distillates. Then by plotting the results with the respective weights as abscissæ, and the corresponding compositions as ordinates, and extending the curve so obtained to the composition axis, we should obtain *the composition of the first infinitely small amount of distillate given off by the mixture,* in other words, the composition of the vapor in equilibrium with that mixture. In reality we do not take six separate samples, but a single sample of moderate weight, and distill off half a dozen consecutive quantities, several grammes each. A simple arithmetical computation gives us the results that *would* be obtained in the imaginary experiment just outlined. As to the reliability of the exterpolation, experience has shown that the curves obtained are exceedingly smooth and that the graphic exterpolation involved is attended with no doubt whatever. Fig. 3 reproduces the curves obtained in the case of carbon disulphide and carbon tetrachloride.

A second phase of the same method is as follows: Knowing the weights and compositions of our actual distillates Nos. 6 and 5, it is easy to calculate the weight and composition that *would* be obtained by mixing 6 and 5 together. Similarly, it is easy to find the weight and composition that would result from mixing 6, 5, and 4, then 6, 5, 4, and 3, etc. We now make the weight of 6 an abscissa and its composition an ordinate, the combined weight of 6 and 5 another abscissa and their combined composition another ordinate, etc. The upper ends of the ordinates lie on a new curve, which we again extend until it meets the composition axis. The curve represents the course of what may be called *a reversed distillation,* and the point in which it meets the composition axis gives the first infinitely small amount of vapor that would return to the given mixture (that is, to the residue from the distillation involved in the first phase of the method). In other words, if we determine the composition of the residue by analysis, the point in question on the curve shows what vapor can exist in equilibrium with that residue (see Fig. 3).

In this manner, driving off half a dozen consecutive samples yields two points of the required vapor-composition curve. Such a distillation takes about ten to twelve minutes.

FIG. 3.

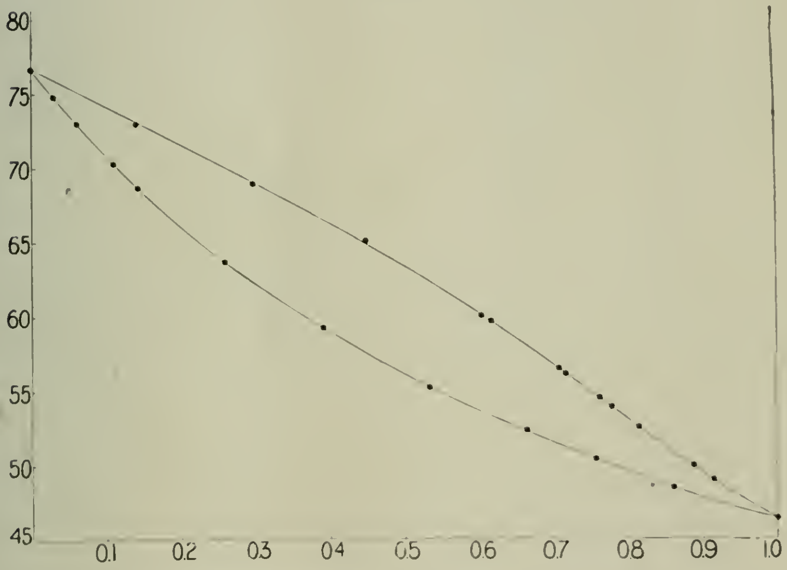


If any time is consumed, it is rather in determining the indices of refraction of the six distillates for the purpose of analysis, each determination taking about five minutes. The method is, therefore, extremely rapid. On the other hand, the simplicity of manipulation is such that an undergraduate student could be trained in a few days to make determinations of considerable precision. *But the greatest advantage of the method will often* *consist in the possibility of using it with small quantities of substance.*

It would be easy to show that by collecting a larger number of distillates it is possible to obtain at once a larger number of points on the vapor composition curve. But I will not insist.

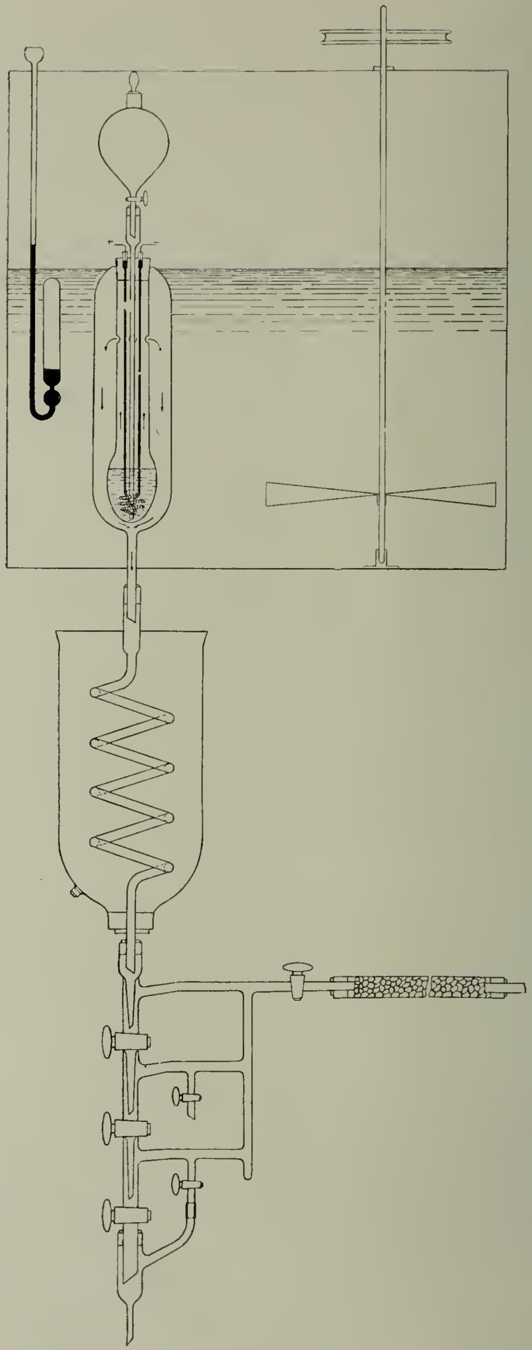
Fig. 4 reproduces the results yielded by the method in the case of carbon disulphide and carbon tetrachloride. The lower curve represents the boiling points of the various possible mixtures. The upper curve represents the composition of the vapors in equilibrium with the liquid mixtures. Any two points of the two curves lying on the same horizontal line have for their abscissæ, respectively, the composition of a liquid and its vapor, counted in molar fractions of carbon disulphide from left to right.

FIG. 4.



The apparatus devised for carrying out these distillations without reflux condensation is shown by Fig. 5. A pear-shaped vessel similar to a Kjeldahl flask, surrounded by a glass jacket fused on to it, contains the liquid to be distilled. Heat is supplied electrically by a platinum wire. The cork closing the flask carries, besides the heater, a funnel through which the liquid

FIG. 5.



is introduced. The vapor escapes through four circular holes in the neck of the flask downward through the jacket into a condensing coil surrounded by a freezing mixture, and from there into the several compartments of the receiving vessel. The vapor itself, surrounding the inner boiling vessel, prevents condensation within it. To further insure this effect, the distillation apparatus is in a thermostat whose temperature is several degrees higher than that of the boiling liquid.

§3. *A New Relationship between the Total and Partial Pressures of Binary Mixtures.*

A study of the extant data on the partial pressures of binary mixtures, combined with Konovaloffs' semi-quantitative principles relating to the shape of the total pressure curve, has guided us to the construction of an expression which correlates the total and partial pressures and permits of *calculating the latter from the former.*[9]

Konovaloff's principles indicate that the steeper the total pressure curve, the more different is the composition of the vapor from that of the liquid. The composition of the vapor is expressed by the ratio p_1/p_2, the composition of the liquid by $x/(1-x)$, and the relation between liquid and vapor by the quantity,

$$\frac{p_1(1-x)}{p_2x}.$$

When the total pressure curve passes through a maximum or minimum

$$\frac{d\pi}{dx} = 0,$$

where π denotes the total pressure. At the same time vapor and liquid are identical in composition, and hence

$$\frac{p_1(1-x)}{p_2x} = 1.$$

This points to the differential coefficient of π with respect to x being a logarithmic function of the relation between vapor and liquid. Assuming it to be simply proportional to the logarithm, we have

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[9] A more detailed account of this relationship will shortly be published in a joint paper with C. W. Bacon.

$$\frac{d\pi}{dx} = k \log \frac{p_1(1-x)}{p_2x}.$$

Further, in case the total and partial pressure curves are all straight lines (G. N. Lewis's "ideal solutions"), then

$$\frac{d\pi}{dx} = P_1 - P_2$$

and

$$\frac{p_1(1-x)}{p_2x} = \frac{P_1}{P_2}.$$

In order that the above relationship should include this case also, it is necessary that

$$k = \frac{P_1 - P_2}{\log P_1 - \log P_2}.$$

We thus have in general:

$$\frac{d\pi}{dx} = \frac{P_1 - P_2}{\log P_1 - \log P_2} \log \frac{p_1(1-x)}{p_2x}.$$

We have tested out this semi-theoretical equation in a number of typical cases and have found it to yield results of great precision. The method of procedure is as follows.

The isothermal total pressure curve is expressed in the form of a parabolic function of the fourth degree in x. This gives the value of the constant

$$\frac{P_1 - P_2}{\log P_1 - \log P_2}.$$

Differentiating, and dividing the differential coefficient by the constant, we get an expression of the third degree in x, which is equated to

$$\log \frac{p_1(1-x)}{p_2x},$$

Knowing the total pressure p_1+p_2, it is then easy to find the values of the partial pressures.

By way of an example, I will reproduce the results obtained in the case of carbon tetrachloride and benzene. The total and partial pressures of this system have been measured by Zawidzki (loc. cit.) at 50°. Zawidzki's total pressure curve was expressed, with the aid of the method of least squares, by the equation

$$\pi = 268.075 + 80.853x - 43.826x^2 + 16.531x^3 - 13.695x^4.$$

In Table II[10] the first column gives the molar fractions of the several liquids studied by Zawidzki; the second column gives the experimental values of the total pressures; the next column gives the calculated values of the total pressures, showing how well the above equation reproduces the experimental results; the fourth column gives the experimental values of the partial pressures of carbon tetrachloride; the fifth column gives the same partial pressures calculated from the total pressures by the method just outlined; finally, the sixth column gives the percentage differences between calculation and experiment. These differences amount for the most part to only 0.1 to 0.2 per cent.

Table II.

x	π obs.	π calc.	p_1 obs.	p_1 calc.	Diff. per cent.
0.0507	271.8	272.1	18.5	17.8	—0.25
0.1170	277.6	277.0	40.5	40.2	—0.11
0.1758	281.5	281.0	59.7	59.6	—0.03
0.2515	285.4	285.8	82.9	83.9	+0.35
0.2947	288.3	288.4	97.0	97.5	+0.17
0.3953	294.5	293.9	128.7	128.7	0.00
0.5587	301.0	301.1	176.4	177.9	+0.17
0.6755	305.2	304.9	211.8	212.9	+0.13
0.7652	306.8	307.0	238.5	238.4	—0.03

§4. *A Theory of Fractional Distillation Based on the Relationship Developed in* §3.

The principal question to which a quantitative theory of distillation must give answer may be formulated in simple terms as follows: Given a mixture containing $100x_0$ molar per cent. of one of the components; what per cent. by weight of the whole must be distilled off in order to change the composition from $100x_0$ to $100x$?

Konovaloff's theory of fractional distillation, given in all text-books of physical chemistry, while rigorously correct, is also purely qualitative and incapable of solving such a problem.

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[10] Computed by C. W. Bacon.

A quantitative theory, proposed some years ago by Barrell, Thomas, and Young,[11] and which may be found in the later editions of Nernst and other text-books, is based on a formula introduced by Brown.[12] According to this, the ratio of the weights of the two components in the vapor is at every instant proportional to their ratio in the liquid:

$$\frac{d\xi}{d\eta} = c\frac{\xi}{\eta},$$

or

$$\frac{d \log \xi}{d \log \eta} = c.$$

That Brown's formula cannot be generally true, may be seen as follows: At a maximum or minimum of the total pressure curve,

$$\frac{d\xi}{d\eta} = \frac{\xi}{\eta}$$

and hence, in general, according to Brown's formula,

$$c = 1.$$

But this would mean that liquid and vapor are identical for *all* compositions, which is obviously untrue. In view of this it is not surprising that experiments failed, in most cases, to agree with the theory based on Brown's formula.

A truer answer to the above question has been given by Lord Rayleigh.[13] But Lord Rayleigh's formulation requires a knowledge of the partial pressures in each special case.

The relationship developed in the previous section permits of answering our question and of foretelling the course of a fractional distillation apparently with precision, on the basis of nothing but a knowledge of the total pressure curve at some constant temperature not too far removed from those observed during the distillation (since, again, the constants a_2, a_3, and a_4 remain unchanged within moderate temperature ranges). It may be added that the determination of an isothermal total pressure curve is scarcely more difficult than the determination of an ordinary boiling-point curve.

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[11] *Phil. Mag.* (5), 37, 8 (1894).

[12] See Young, "Fractional Distillation" (London, 1903), p. 93.

[13] *Phil. Mag.* (6), 4, 521 (1902).

Let ξ and η represent respectively the absolute *weights* of the two components in the liquid, and $d\xi$ and $d\eta$ their absolute *weights* in the vapor. Then

$$\frac{d\log\xi}{d\log\eta}=\frac{p_1(1-x)}{p_2x}.$$

Further, if we write, for the sake of brevity,

$$\frac{P_1-P_2}{\log P_1-\log P_2}=\frac{1}{S},$$

the equation of §3 assumes the form

$$\frac{d\log\xi}{d\log\eta}=e^{\frac{Sd\pi}{dx}}.$$

It is easy to see, further, that

$$d\log\eta=d\log\xi-\frac{dx}{(1-x)}$$

Therefore,

$$d\log\xi=\frac{e^{\frac{Sd\pi}{dx}}}{\left(e^{\frac{Sd\pi}{dx}}-1\right)(1-x)\,x}\cdot dx,$$

and if ξ_0 is the original weight of the first component,

$$\log\frac{\xi}{\xi_0}=\int_{x_0}^{x}\frac{e^{\frac{Sd\pi}{dx}}}{\left(e^{\frac{Sd\pi}{dx}}-1\right)(1-x)\,x}\cdot dx.$$

Similarly,

$$\log\frac{\eta}{\eta_0}=\int_{x_0}^{x}\frac{dx}{\left(e^{\frac{Sd\pi}{dx}}-1\right)(1-x)\,x}.$$

These equations have been tested experimentally by C. W. Bacon in collaboration with the writer, and the agreement between theory and experiment was nearly perfect. For example, working with ethyl iodide and ethyl acetate: in order to produce a given change of composition, in one case, theory required that 37.42 per cent. must be distilled off. The change was actually produced by distilling off 37.44 per cent.

If the total and partial pressure curves are straight lines, the equations are much simplified. We get

$$\frac{\xi}{\xi_0} = \left[\frac{x(1 - x_0)}{x_0(1 - x)}\right]^{\frac{P_1}{P_1 - P_2}},$$

$$\frac{\eta}{\eta_0} = \left[\frac{x(1 - x_0)}{x_0(1 - x)}\right]^{\frac{P_2}{P_1 - P_2}},$$

and

$$\frac{d \log \xi}{d \log \eta} = \frac{P_1}{P_2} = \text{constant}.$$

The last equation is readily recognized as Brown's formula, which thus appears as a special case of our more general relationship. The Brown-Young theory of distillation is, consequently, quite correct; but it applies only in the rare, almost exceptional, cases in which the vapor pressure curves are straight lines.

Other distillation studies carried on in these laboratories during the past two years dealt with the constant temperature still-head. On this work I hope to report in a future communication.

In conclusion, it is a pleasure to acknowledge my indebtedness to the Rumford Committee of the American Academy, for a grant without which our distillation work could not have been done.

Production of Tin Plate in the United States. Anon. (*Amer. Mach.*, xxxv, 168.)—Tin plate makes a new record in two or three particulars in United States commerce statistics for the late fiscal year. The imports are lower than in any year since the records began, the exports are larger than ever before, and for the first time the exports exceed the imports. The imports of tin plate fall below 100 million pounds. In the last six months of 1891 the home production was 2¼ million pounds. In 1892 it was 42 million pounds, and from that time on increased rapidly, and in 1897 exceeded 500 million, and in 1903 reached 1075 million pounds. In 1906 the production reached 1294 million pounds, and in 1909 it amounted to 1371 million pounds.

ELECTRICAL METHODS OF INTERCOMMUNICATION FOR MILITARY PURPOSES.[1]

BY

GEORGE O. SQUIER, Ph.D.,

Major Signal Corps, U. S. Army.

THE Signal Corps of the United States Army maintains military lines of information by telegraph and telephone (radio, aerial wire, and submarine), by visual signalling, by air-machines, and by other collateral methods. It also devises and furnishes the electrical apparatus for the fire-control and fire-direction system of both the coast defenses and of field artillery. Incidentally it operates for commercial purposes military telegraph lines when such lines are not occupied with official business.

ALASKA.

The Signal Corps has constructed, and maintains and operates, the Washington-Alaska Military Cable and Telegraph System for official and commercial purposes. This system, at the present time, consists of 2,633 miles of submarine cable, 1,125 miles of land lines, and nine wireless stations. For purposes of administration and supply, the system is divided into four sections, with officers of the Signal Corps in charge. The lines from Valdez to Paxson comprise the first section, and are supervised by the Signal Corps officer at Valdez. The lines from Paxson to Glen, and from Fort Egbert to Boundary, together with the wireless stations at Fairbanks, Circle, and Fort Egbert, comprise the second section, and are supervised by the Signal Corps officer at Fairbanks. Those from Glen to Kaltag and the wireless station at Fort Gibbon comprise the third section, the officer in charge being stationed at Fort Gibbon; while the lines west of Kaltag and the wireless stations at St. Michael, Nome, and Kotlik comprise the fourth section, with the officer in charge stationed at St. Michael.

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[1] Abstract of a paper presented at the joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, October 12, 1911.

Below is given a list of stations and distances, corrected to date:

LAND LINES.

St. Michael–Valdez.

	Intermediate	Total
St. Michael	1	1
Golsova	42	43
Unalakleet	24	67
Old Woman	40	107
Kaltag	50	157
Nulato	37	194
Koyukuk	20	214
Louden	62	276
Melozi	29	305
Kokrines	37	342
Birches	38	380
Fort Gibbon	63	443
Rapids	36	479
Rampart	34	513
Glen	28	541
Hot Spring	22	563
Tolovana	32	595
Minto	42	637
Nenana	32	669
Chena	41	710
Fairbanks	12	722
Salcha	36	758
Delta	27	785
Richardson	12	797
McCarty	21	818
Donnely	36	854
McCallum	36	890
Paxson	19	909
Hogan	30	939
Gulkana	36	975
Copper Center	26	1,001
Tonsina	25	1,026
Teikhell	24	1,050
Beaver Dam	16	1,066
Wortmans	20	1,086
Valdez	19	1,105

Nome–Fort Davis.

Nome, city office	0	1,105
Nome, wireless	0.5	1,105.5
Fort Davis	4	1,109.5

Egbert–Boundary

Fort Egbert, wireless	0	1,109.5
Fort Egbert	1.5	1,111
Boundary (no station)	13.5	1,124.5
Fairbanks, wireless to city office	1	1,125.5

CABLES.

Seattle–Seward.

	Intermediate	Total
Seattle	0	0
Sitka	1,087	1,087
Valdez	599	1,686
Fort Liscum	4	1,690
Seward	196	1,886
Montague Island-Cordova-Cape Whitshed	69	1,955

Sitka–Skagway.

Sitka	0	1,955
Cape Fanshaw (no station)	212	2,167
Juneau	98	2,265
Haines Mission	107	2,372
Skagway	18	2,390
Juneau–Douglas	3	2,393

Cape Fanshaw-Ketchikan.

Cape Fanshaw (no station)	0	2,393
Wrangell	74	2,467
Ketchikan	113	2,580

Lawton–Worden.

Fort Lawton	0	2,580
Fort Worden	40	2,620

Ward-Lawton.

Fort Ward	0	2,620
Fort Lawton	13	2,633

Sitka–Japonski Island.

Sitka	0	2,633
Japonski Island	0.35	2,633

WIRELESS.

Egbert–Circle	110	.....
Circle–Fairbanks	126	.....
Egbert–Fairbanks	190	.....
Fairbanks–Gibbon	135	...
Gibbon–St. Michael	330	.....
Nome–St. Michael	127	.....
St. Michael–Kotlik	52	.....
Kotlik–Nome	122	.....
Petersburg–Wrangell	30	.....

RECAPITULATION.

	Miles
Land lines	1,125.5
Cables	2,633
Total	3,758.5

Wireless stations, 9.

Signal Corps wireless telegraph station at Fairbanks, Alaska. Part of a chain of wireless stations on the Yukon River.

RADIO-TELEGRAPHY.

The Signal Corps is responsible for the purchase, installation, and operation of wireless telegraphy for the army. The scope of this work requires widely different types of apparatus and methods, from the light portable sets which are transported on muleback, for cavalry service in the mobile army, to the larger permanent stations along the Yukon River in Alaska and at the larger military posts in the United States. For strategical purposes high-power stations have been installed at Fort Leavenworth and Fort Riley, Kans., and Fort Omaha, and such a station is at present being constructed at San Antonio, Tex., which it is expected will have a range of 600 to 1,000 miles at all times. Below is given a list of the wireless telegraph stations installed by the Signal Corps, corrected to date:

Signal Corps field wire telegraph section for use with infantry and mixed commands. The Manœuvre Division, San Antonio, Texas, May, 1911.

UNITED STATES.

Name of Station	Call letter	Power k w.	Whether open to public service
Fort Andrews, Mass.	FC	1	Not open to public service.
Fort H. G. Wright, N. Y.	FW	1	"
Fort Hancock, N. J.	FN	1	"
Fort Leavenworth, Kans.	FL	3	"
Fort Levett, Me.	FV	1	"
Fort Monroe, Va.	FO	1	"
Fort Omaha, Nebr.	FS	3	"

Name of Station	Call letter	Power k.w.	Whether open to public service
Presidio, San Francisco.	PS	1	Under construction.
Fort Riley, Kans.	FZ	3	Not open to public service.
Fort Totten, N. J.	FT	¾	"
Fort Wood, N. Y.	FD	3	"
Fort Worden, Wash.	FX	1	"
Sig. Corps Laboratory, Wash., D. C.	SC	3	Experimental.
Fort Stevens, Oreg.	FJ	1	Not open to public service.
Bureau Standards, Wash., D. C.	BS	2	Experimental.
ALASKA.			
Circle City	FK	3	Open to public service.
Fort Ebgert	FQ	5	"
Fairbanks	FB	5	"
Fort Gibbon	FG	10	"
Kotlik	FE	1	"
Nome	FD	10	"
Nulato	....	10	Under construction.
Petersburg	FP	1	Open to public service.
Fort St. Michael	FM	3	"
Wrangell	FW	1	"
PHILIPPINE ISLANDS.			
Corregidor Island	FH	10	Under construction.
Fort Drum	PIB	⅛	Not open to public service.
Fort Frank	PIA	⅛	"
Manila	PN	1	"
Fort Wm. McKinley	PID	¾	"
Fort Wint	PIC	1	Under Construction.
U. S. ARMY TRANSPORT SERVICE.			
Buford	ATB	2	Open to public service.
Crook	ATC	2	"
Dix	ATD	2	"
Kilpatrick	ATK	2	"
Liscum	ATM	2	"
Logan	ATL	3	"
Sheridan	ATS	3	"
Sherman	ATR	3	"
Sumner	ATH	3	"
Thomas	ATU	3	"
Warren	ATW	2	"
Cableship Burnside	BS	3	"
Cableship Joseph Henry	FR	2	"
Cableship Cyrus W. Field	FA	1	"
ARTILLERY HARBOR TUGS.			
Captain Rowell	RW	⅛	Not open to public service.
Reno	X	½	"
General Randall	OR	⅛	"
General R. B. Ayer	FY	⅛	"
Harvey Brown	HB	½	"
James Fornance	ASF	⅛	"

PHILIPPINE ISLANDS.

At the outbreak of the Spanish-American war the Philippine Islands had no adequate telegraph facilities, and one of the first steps taken in the pacification of that country was to cover it with a net-work of wires and cables.

In 1900 the first American cableship, the United States transport "Burnside," was fitted out in New York harbor and dispatched to Manila, *via* the Suez Canal, laden with the first American-made submarine cable ever constructed for telegraph purposes.

During the years 1900 to 1903 this expedition connected all of the principal islands of the Philippine group and joined these cables to the extensive system of land lines which had been constructed by the Signal troops on duty with the American army of occupation. This system, when completed, comprised 6,322 miles of land lines and 1,437 miles of cable, which was maintained and operated by the Signal Corps for official and commercial purposes until 1907, when it was turned over to the civil authorities in those islands, where it is still rendering a most indispensable service. The Signal Corps retains, however, certain special lines for strategic and administrative purposes of the army.

2 k.w. quenched spark field headquarters wireless set for communication with troops along the Mexican border. The Manœuvre Division, San Antonio, Texas, May, 1911.

SIGNAL SCHOOL FOR OFFICERS.

The Signal Corps maintains a technical school for the special training of officers of the regular Signal Corps and the line of the army.

The object of the Signal School is to prepare the officers of the Signal Corps for the better performance of the active duties of their profession, to provide instruction in signal duties for such officers of the line as may be designated therefor, to make researches and practical experiments in such subjects as relate to the duties of the Signal Corps, and to disseminate information so obtained.

This school is located at Fort Leavenworth, Kans., where is also the Army School of the Line, the Army Staff College, the Army Engineering School, and the Army Medical School. It enables the Signal Corps to most advantageously study, determine, and test the duties which would be required of it in campaign in conjunction with the other arms of the service.

SIGNAL SERVICE FOR THE MOBILE ARMY.

The one unchanging factor. in warfare is the individual physical strength of a man. The soldiers of Cæsar's army were physically no stronger nor weaker than our own. Progress in the art of war, therefore, consists in the realization of certain fundamental conceptions from time to time, and the seizure of one idea at a time, working it out in detail, and applying it before an enemy realizes its importance. These fundamental ideas have been slow to impress themselves upon military leaders, and, therefore, that nation which first takes hold of a new fundamental principle in war, and works it out with the greatest perfection in time of peace, possesses an insuperable advantage when suddenly the conflict is precipitated.

Frederick the Great inherited an army which had been trained in peace, and he soon found out that he could march all around his enemies and strike them where he pleased. Napoleon, for the first time, grasped the importance of the relation between the ground and the battle, and developed this single idea until the French nation led the world in war. The electric telegraph was then unknown, but it is not too much to say that if there had been on duty with Napoleon's army at Waterloo a single trained company of signal troops, such as is now at the United States Signal School, the history of modern Europe would probably have been different.

The strictly modern art of war began with the campaign of Metz and Sedan in 1870. The greatest of the fundamental ideas introduced in the art of war at that time concerned the mobilization and accurate assembling of great armies upon the field of battle. The army of the North German Confederation in the peace establishment numbered 12,000 officers, 285,000 men, and 73,000 horses. The order to mobilize was telegraphed on July 16. Between July 23 and 25 the army was increased to 22,000 officers, 932,000 men, and 193,000 horses, ready for war. The mobilization having been completed in eight to ten days, in eight to ten days more a force of nearly half a million of men and 1,200 guns, with first and second lines of trains complete, was assembled on a line of about ninety miles from Treves to Germersheim, waiting for the order to advance. This result was effected by using railroad facilities to an extent unknown before.

Signal Corps wireless pack telegraph equipment for use with cavalry. The Manœuvre Division, San Antonio, Texas, May, 1911.

GRAPHIC COMMAND.

The range and accuracy of modern artillery fire and the extended order in which troops at the present time operate have enabled us to form some rough estimate of the size and area of the modern twentieth-century battle-field.

With armies of the size which certain of the first-class powers may reasonably be expected to employ in a contest, the number of square miles which may be involved in the tactical use of such armies under one single command becomes so great that the military student is immediately confronted with the following serious questions: How is it possible for one brain or set of brains to be provided with efficient means of controlling and accurately commanding from hour to hour the vast assemblage of men and supplies which constitute the complex aggregation which goes to make up the modern army in the field?

It is certain that there must be some one supreme authority for such an army in order to secure that perfection of "team play" which lies at the bottom of all military success.

First. What means and accessories, therefore, can be provided by modern science to place in the hands of a supreme commander of an army the machinery which will enable him and his expert staff to digest the mass of military information which may be poured in upon him, not only from the operations of the troops themselves in combat, but also concerning the movements of the equally necessary supplies of all kinds which are required for the maintenance of that army? and—

Second. What sure and certain means may be furnished for the commander-in-chief to make the best use of this military information to direct the different units of his command from hour to hour over this vast area to effect an optimum in the co-operation of the three fundamental arms of which his command is composed?

In seeking an answer to the above military inquiries, we are forced to two general principles which are at the foundation of the solution of these questions:

(*a*) We must adopt the electrical messenger.

(*b*) We must assist the mind to grasp this complex and ever-changing panorama by the well-known advantages of graphics.

The electrical messenger has no competitor when the distances involved in the modern battle-field are considered. It travels at a rate so great as to make all terrestrial distances equal for practical purposes, which means that the most distant point of the battle-field is equally near for purposes of command to any other point.

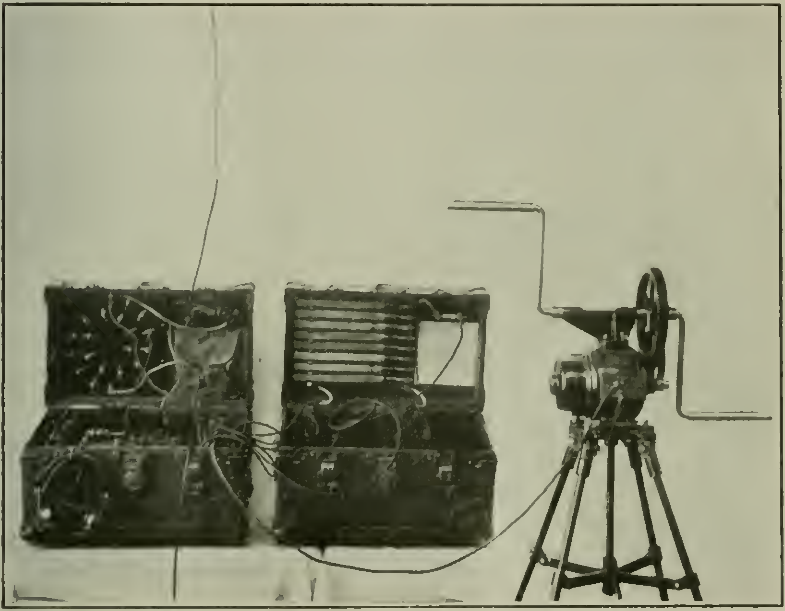
No human brain is able or brilliant enough to picture and follow in their relative positions the necessary elements of a large army, and the principle of graphics is the best known practical means at present to enable that brain to see his army in miniature in its ever-changing evolutions, and consequently to formulate effective commands to control these evolutions.

Having determined on the two fundamental principles which are necessary and sufficient in attacking the solution of this problem, it remains to develop them by long-continued practice in the field to the limit of possible usefulness. The perfection of these principles into a practical working machine by which the supreme commander, if need be, can command his forces, from a fixed point, may be called "graphic command" or "graphic control."

In the execution of "graphic command" for large forces in the field we are led to a conception of field headquarters radically different than was the case when great generals of the past operated their forces largely by commands given personally on the field. We may picture the commanding general of the future surrounded by his expert staff, each a specialist in his arm or staff department, occupying a more or less fixed point located in combat between his advance combatant troops in front and his supply train in rear. The exact location of field headquarters would depend on a number of circumstances, but evidently should be far enough removed from the actual fighting as to permit that calm and cool judgment on the part of both the commanding general and his staff which is a prime requisite at all times.

With large armies it would ordinarily be from ten to thirty miles in rear of the advance line, and in such comfortable buildings as the terrain affords. The commanding general should be carefully guarded from fatigue and provided with every means possible for his physical comfort. From this view-point it is even conceivable that a man may attain eminence as a general in the military profession at present without ever having been actually under fire.

During two separate manœuvre periods in the month of May, 1911, at Leon Springs, Tex., with the entire manœuvre division, the actual machinery of "graphic command" was carried out with marked success. Copies of the actual field messages sent and received, and the "graphic map" constructed by the Signal Corps, were turned over each day to the Chief of Staff after the completion of the manœuvre, and formed the "war diary" called for by Field Service Regulations.



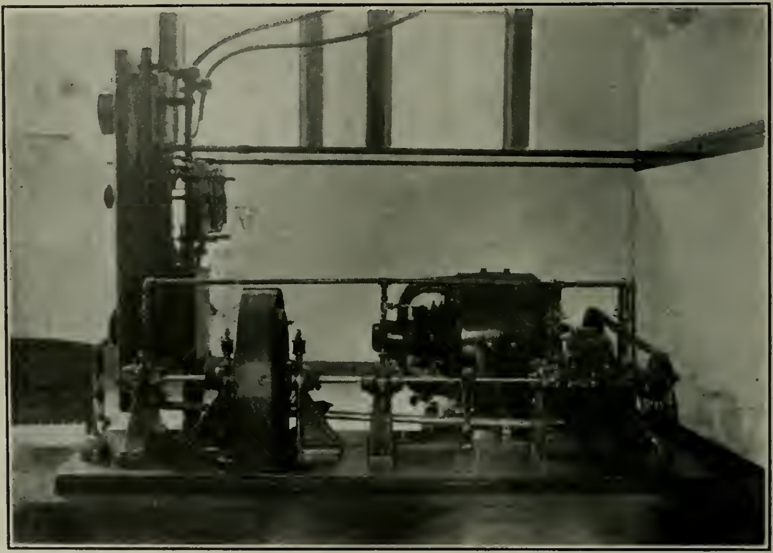
Field wireless pack set for cavalry operations. Power supplied exclusively by hand generator, shown at right of photograph. The two trunks are transported on a single mule. The Manœuvre Division, San Antonio, Texas, May, 1911.

Wireless pack equipment was used invariably for cavalry operations, and field wire used for infantry and mixed commands, and all movements of the units were ordered by telegraph from temporary headquarters in the field and such movements plotted on the headquarters map by a signal officer.

SIGNAL CORPS RESEARCH LABORATORY, BUREAU OF STANDARDS.

In the development of special apparatus for the technical equipment of field companies for the mobile army, for fire control and direction of coast fortifications, and for wireless intercommunication at permanent and semi-permanent stations, the Signal Corps is constantly required to carry on engineering work of research character.

Under a special appropriation granted to the Signal Corps by Congress in the army appropriation act of 1909, a small research laboratory has been established at the Bureau of Standards, in the suburbs of the city of Washington. This laboratory is equipped with the latest forms of apparatus now employed in the wireless telephone and telegraph art, and also with the standard types of telephone and telegraph apparatus now used upon wire circuits. The small construction laboratory of the United States Signal Corps is located at 1710 Pennsylvania Avenue, and is also equipped with the usual types and forms of apparatus used in transmitting intelligence by electrical means. Each of these laboratories is supplied with a wireless telephone and telegraph installation with suitable antennæ. In addition, these two laboratories are connected by a standard telephone cable line about seven miles in length.



100,000 cycle high-frequency generator. Signal Corps Research Laboratory, Bureau of Standards, Washington, D. C.

A special type of high-frequency alternator[2] is installed in the research laboratory, which has unique characteristics and enables experiments to be conducted through a range of frequencies of from 20,000 to 100,000 cycles per second. Attention is invited to this machine here for the reason that it is believed that this type offers rare opportunities for engineering research work to fill in the gap between wire telephony and telegraphy and pure radio-telephony and telegraphy. This generator is of the inductor type, and the rotor is a disk one foot in diameter, which revolves at a speed of 20,000 revolutions per minute to generate electric waves of 100,000 cycles per second.

The machine is intended to be used with a condenser, the capacity reactance of which balances the armature inductance reactance, which is 5.4 ohms at 100,000 cycles. This would require a capacity of about 0.3 microfarad for resonance at this frequency.

The air-friction or adhesion of this disk revolving at the above speed is over 5 k.w. or is greater than the total electrical output, which is 2 k.w., so that a 10 h.p. motor is required to operate it properly.

American Society of Mechanical Engineers.—The annual meeting of the society will be held in New York City, December 5–8 inclusive.

Business and professional meetings will be held in the Engineering Societies Building.

Several excursions and inspections have been planned; a lecture will be given on December 6, and a reunion will take place at the Hotel Astor on the following evening.

The Committee on Meetings is composed of Messrs. Fred. H. Colvin, Edward Van Winkle, Roy V. Wright, Frederick A. Waldron, and Walter Rautenstrauch.

Air in the Depths of the Ocean.—In a recent number of *Science* (August 25, 1911), Carl Hering suggests the following possible explanation of how air gets to the bottom of the ocean to support the life of deep-sea fishes and other living creatures who may need oxygen. The amount of gas which a liquid will hold in clear and stable solution increases with the pressure, as illustrated by champagne. The top layer of water in the ocean may be assumed to be saturated with all the air it can hold; the next layer beneath is under a higher pressure, hence holds more; there will, therefore, necessarily be a transference of air from the upper to the next lower layer to bring about stability. This process must continue downward to the most extreme depths at which the amount of air per unit volume would be greatest, because the pressure is greatest. The deep-sea fishes would, therefore, be enjoying richer air than those near the surface, and if they consume the oxygen, and the plants possibly the nitrogen, there should be a constant flow of air from the top to the bottom of the ocean.

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[2] Alexanderson, *Trans. A. I. E. E.*, vol. xxviii, p. 390, 1909.

The Extrusion of Metals in the Solid State. ANON. (*Iron Age,* lxxxv, 1507.)—Extruding means forcing the metal in a solid condition through a die by applying pressure behind the mass to be extruded. By extrusion zinc is transformed into a fine crystallized structure, with a tensile strength of 23,000 pounds per square inch, as compared with its ordinary tensile strength of 120 pounds per square inch. Aluminum, copper, and lead can be extruded with excellent results.

Selenium Photometer. ANON. (*Ges. für Elektrotechnische Ind., French Pat.* 425,854 of 1911.)—This is the type of photometer in which a rotating mirror, mounted obliquely to its axis of rotation, directs the light alternately from each of the two sources to be compared, on to a selenium element through which a continuous current is passed, this element being connected in series with two windings producing a magnetic field of constant direction, and in which a small coil, through which an alternating current is passed synchronizing with the alternations of the light falling on the selenium element, is suspended in this magnetic field so as to oscillate about the zero point when the lights are of equal intensity. In order to increase the sensitiveness of the instrument by using stronger currents, and at the same time to prevent the rapid oscillations of the needle, the field due to the continuous current passing through the selenium element is weakened by separate opposed windings or by a permanent magnet. In one arrangement the mirror, which has reflecting surfaces at both back and front, is mounted between two selenium elements. These elements are in independent circuits, having opposed windings, so that the variations of the field due to the two elements are in the same sense. The same effect may also be obtained using two separate mirrors. In another arrangement the selenium element is in the primary circuit of a transformer, and the secondary circuit contains two windings for producing the field in which the coil is suspended, through which the alternating current is passed. When the two lights are of equal intensity, there is no current in the secondary of the transformer and the needle of the suspended coil is in the zero position.

A BISMUTH-SILVER THERMOPILE.

BY

W. W. COBLENTZ, Ph.D.,
Associate Physicist, Bureau of Standards.

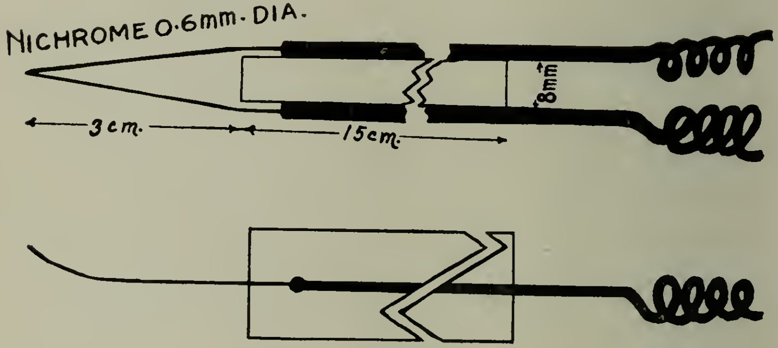
Being able to purchase fine bismuth wire (from Hartmann and Braun), an attempt was made to use a pile constructed of bismuth iron, soldered with Wood's alloy. The iron was first tinned so as to make good contact. It was found that the resistance of a single junction arose from 1.5 ohms to 3 ohms, and some to 90,000 ohms, in a few days, and the whole was therefore discarded. In view of the fact that iron rusts easily, that the Bi-Fe junctions were weak, and that the thermoelectric power of Fe is about five times that of Ag, while its resistance is from six to ten times that of Ag, there is no particular advantage in using iron instead of silver. The welding of bismuth to silver makes a very strong junction. It was found that the direct welding of Bi to Ag was somewhat difficult. A small bead of tin, about 0.1 mm. in diameter, was therefore melted to the silver wire(Ag.=.051 mm. diameter) by means of a small heater of nichrome wire filed thin at the point, shown in Fig. 1. The end of the bismuth wire (Bi = 0.1 mm. diameter) was then brought into contact with this bead of tin (probably an alloy of Sn and Ag), which was then melted with the nichrome heater. Contrary to some of the prevailing notions, such a heater is better adapted to delicate work of this type than is a well-tinned soldering copper; for the surface tension of the molten material on the hotter surface of an ordinary soldering instrument is sufficient to tear fine bolometer strips. The bismuth wire is too brittle to permit flattening the junction, so that a small rectangle of pure tin 1.4 × 0.6 × 0.025 mm. was then placed under the Bi-Ag junction and fused thereto with a quick touch of the nichrome heater. It is somewhat easier to flatten the tin bead attached to the silver wire and then fuse the bismuth to this flat disk (see lower part of Fig. 2), but in this case it is not so easy to produce a receiving surface which completely fills the thermopile slit. Sheet silver, 0.02 mm. in thickness, is better than tin for a receiving surface.

because it does not melt in attaching it to the junction. In this case the tinned silver wire may be attached to the sheet of silver and then the bismuth wire is melted thereto.

There are many points in favor of the use of silver instead of copper in this type of thermopile. It is easily annealed and the brown oxide is easily removed by heating the wire on a sheet of metal. Thus cleaned, the bead of tin is easily attached without any soldering acid. A bit of rosin is useful but not necessary in attaching the bismuth wire. The low resistance (0.08 ohm per metre), and especially the pliability of silver, are also important items, which one appreciates after working with iron and constantan wires. The bismuth wire is not so pliable, but it is short, and since it is subject to very little usage in mounting it is not easily broken. Before mounting them the various junctions were given a thin coat of shellac on the rear side, for insulation, and painted with a mixture of lampblack and chemically precipitated platinum black in turpentine on the front surface. The junctions were then mounted, slightly overlapping upon a glass plate, with Le Page's glue, and the ends of the silver wires were soldered together as shown in Fig. 2. The glass plate was then mounted on an ivory frame and the loose ends of the silver wires were attached thereto. The glass plate was then removed by soaking in water, thus leaving a uniform, solid, well-insulated

Fig. 1.

TOP VIEW.

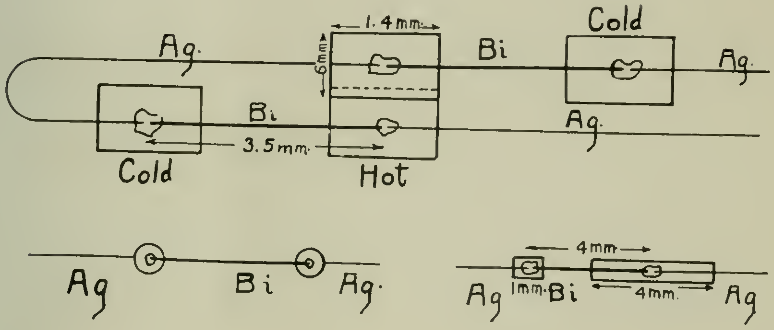


SIDE VIEW.

Nichrome welding instrument.

receiver as shown in Fig 3. Subsequently all these junctions were separated and the resistance of the pile was then found the same as when the junctions were in contact, showing that the insulation was perfect. The silver wires were then given a thin coating of shellac; but this was not necessary. The length of the receiving surface of this pile, consisting of 20 junctions, is 12 mm. The great width, 1.3 to 1.4 mm., of this particular pile was chosen for a special research in which high sensitivity was required. The rectangles or disks of tin may be much smaller, as in the new form of Rubens thermopile.

Fig. 2.

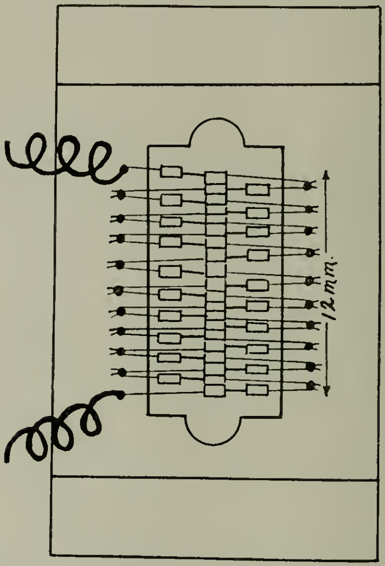


The thermoelectric power of this bismuth-silver thermocouple is 89 microvolts per degree, as compared with an iron-constantan couple which is 51 to 53 microvolts per degree. The *temperature* sensitivity of Bi-Ag is therefore about 74 per cent. greater than an iron constantan thermopile. Whether the *radiation* sensitivity is increased in like proportion will depend upon the selection of the proper diameters of wires, as will be found presently in this thermopile, in which the radiation sensitivity is two to three times that of the iron-constantan pile. The new form of iron-constantan thermopile of fine wires has a resistance of about 9 ohms. The present example of bismuth-silver has a resistance of 9.3 ohms.

The radiation sensitivity of this bismuth-silver pile and of an iron-constantan pile was tested, side by side, by joining the two instruments through a mercury switch to a galvanometer of 5.3 ohms resistance and $i = 4.6 \times 10^{-10}$ ampere. A standard sperm candle placed at a distance of 2.4 m. caused a deflection of 10.2 cm., or 59 to 60 cm. for a candle and scale at 1 metre when the bismuth-silver pile was exposed. With a galvanometer sensitivity three times as large, as it is ordinarily used, the total deflection would have been about 180 cm.

The Rubens thermopile, of wires about 0.15 mm. in diameter and having a resistance of 4.7 ohms, when similarly exposed, caused a deflection of 3.8 to 4.0 cm, or about 23 cm. for a candle and scale at 1 m. The receiving surfaces of this pile were about 1.5 mm. diameter and about 0.2 mm. thick. The disks overlapped so that the 20 junctions occupied a space 20 mm. long. The actual area exposed was therefore greater than in the first bismuth-silver pile, which had a receiving surface of about 16 mm.^{2} This comparison shows that the radiation sensitivity of this bismuth-silver pile is about 2.6 as sensitive as the ordinary Rubens silver pile. If we consider that in spectroradiometry we are interested in the length (height) of the spectrum which can be utilized we should have made the length of the Bi-Ag pile 20 mm. by adding more couples. The radiation sensitivity of the

FIG. 3.



Bi-Ag linear thermopile.

Bi-Ag pile would therefore be increased by 20÷12, or a total deflection of about 100 cm. instead of 60 cm. as observed. It is therefore safe to say that, comparing equal lengths of receiving surface utilized on a spectral line, the radiation sensitivity of this type of Bi-Ag pile is four times that of the old type of low resistance, iron-constantan pile. If we compare the bismuth-silver pile with the fine wire type of iron-constantan pile, which has a resistance of 8.9 to 9.3 ohms and has a radiation sensitivity of 1.4 times that of the old Rubens type of pile, it is a fair estimate to say that this pile has a radiation sensitivity three times as great as the new type of iron-constantan pile.

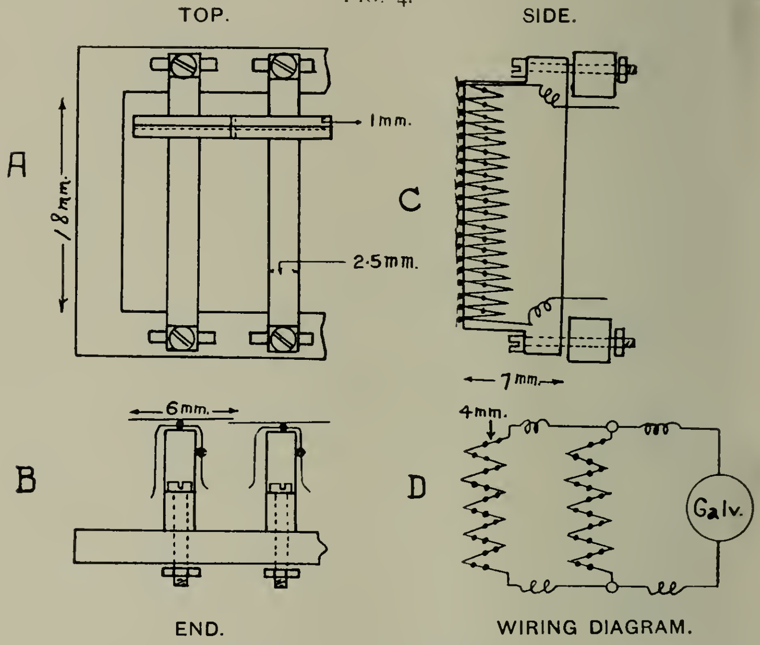
One important point usually not considered is the heat capacity, and hence the speed of attaining temperature equilibrium in these instruments. In the present radiation sensitivity tests the time of single swing of the galvanometer was 2 seconds. When joined with the bismuth-silver pile the half period was lengthened to about 3.8 seconds, which is practically the same as for the new type of fine wire iron-constantan pile. This is not an excessively long period, and the deflection returns abruptly to its zero position. But in the old type (heavy wire) of iron-constantan pile, tested alongside of the bismuth-silver pile, the time of single swing of the galvanometer was increased from 2 seconds to about 6.5 seconds, and there was a tendency to lag, especially when measuring intense radiation, so that it does not compare favorably with the Bi-Ag pile. This pile of bismuth-silver was designed for special work using a large receiving surface in air, where very thin metal is easily affected by air currents. The hot and the cold junctions are sufficiently alike in size and emissivity so that there is no permanent temperature difference and consequent drift in the instrument. The junctions are easily made and mounted, and they are equally easy to repair if broken. The iron-constantan pile of fine wire is difficult to handle and difficult to repair if broken.

By using an alloy of platinum-iridium instead of silver the thermoelectric power would be increased, but owing to the increased resistance it remains to be determined whether a higher radiation sensitivity would be obtained.

The present instrument is not intended for rapid work, but for an exact and undisturbed register of observations with the instrument in air. While the time to attain temperature equilibrium is somewhat longer (less than 4 seconds) than was hoped for, it is not sufficient to cause annoyance. By reducing the heat capacity, by using thinner wires, temperature equilibrium should be attained in less than 3 seconds.

The success attained with the linear pile led to the construction of a thermopile having a large receiving surface built up of single units, each of which contains 20 or more thermoelements, mounted upon an ivory support as shown in Fig. 4, C. In the preliminary tests as to the most desirable widths of strip to be used, thermoelements were built with receivers of the same width, 0.6 mm., and of different lengths, as shown in the lower part of Fig. 2. In all cases the silver wire used was 0.0513 mm. in diameter. The bismuth wires (4 to 5 mm. long) examined were 0.06 and 0.15 mm. in diameter. The two receiving surfaces were blackened, and they were exposed alternately to radiation. The elements to be tested were enclosed in order to avoid air currents. Using bismuth wire 0.15 mm. in

FIG. 4.

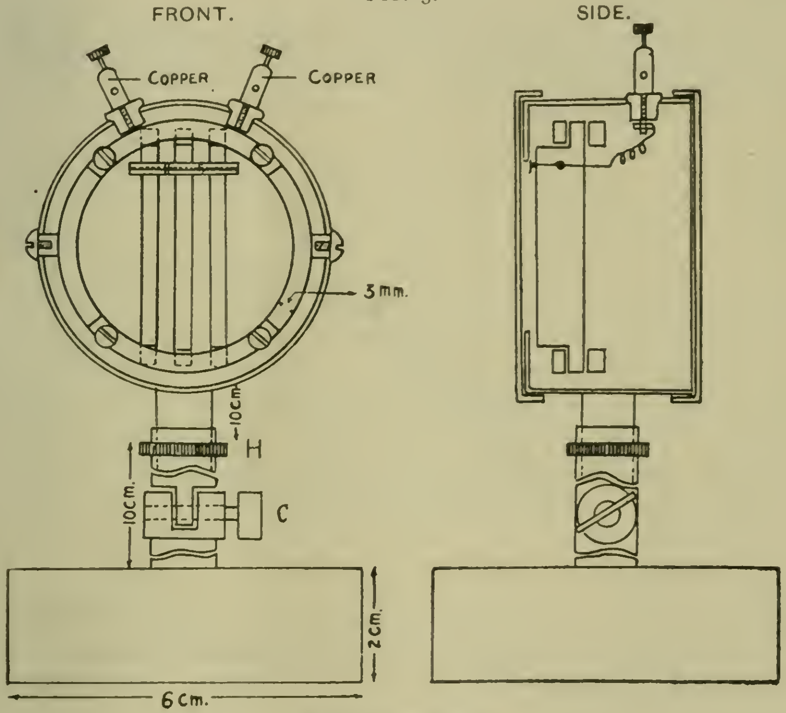


Surface thermopile of bismuth-silver.

diameter, the deflection for a receiver 4 mm. long was not quite twice that of a receiver 1 mm. long. For both receivers the deflection did not attain a maximum abruptly, and there was a serious "creeping" requiring some 15 seconds for the galvanometer to come to rest.

Using bismuth wire 0.06 mm. in diameter the galvanometer deflection for a receiver 4 mm. long was 2.1 times as large as that of the receiver 1 mm. long. On reducing the length of the 4 mm. receiver to about 2.6 mm. the sensitivity was 1.9 times as great as the receiver 1 mm. in length. A receiver 9 mm. long was 2.7 times as sensitive as that of a receiver 1 mm. in length. As shown in Fig. 6, the sensitivity varies roughly as the square root of the receiving surface, which is the law of the surface bolometer. As a matter of fact, there is an optimum length of the order of 2 mm.; but this exact value was not

FIG. 5.

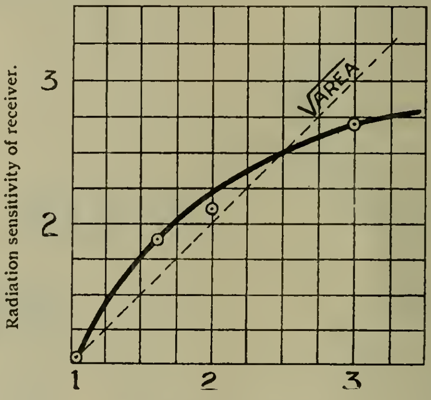


Holder for thermopile.

determined. Obviously two receiving surfaces 4 mm. wide are better than a single one 9 mm. wide in the ratio of 4.2 to 2.7. In fact, the sensitivity would be still greater than this by placing two units (4 mm. wide) in parallel; for the internal resistance is reduced to one-half the former value. Units which are built up with receiving surfaces 4 to 6 mm. wide give ample working space in mounting, so that there is a distinct gain in using such narrow widths.

No difference could be detected in the sensitivity of the front and rear surfaces of these junctions, showing that attaching the junction at the centre of the receiver is not detrimental.

Fig. 6.



Square root of area of receiver.

The size of the receiver made no appreciable difference in the time of attaining a temperature equilibrium. In designing the surface thermopile it was therefore deemed permissible to omit the receiving surfaces from the "cold," unexposed junctions. For fine wire the deflection attained its maximum abruptly in 3 to 4 seconds.

In a vacuum of 0.15 mm. pressure of mercury the thermoelement of bismuth wire 0.06 mm. in diameter was 2.03 times as sensitive as in air. It is therefore a distinct advantage to place the pile in an evacuated enclosure.

Using the same size receivers, the radiation sensitivity of the thermoelement of bismuth wire 0.15 mm. in diameter was twice as sensitive as the element of bismuth wire 0.06 mm. in diameter. But the serious lag in attaining temperature equilibrium in a thermopile of bismuth wire 0.15 mm. in diameter is objectionable, so that it is to be recommended only where a very high sensitivity is required and where the radiation is very weak.

In the surface thermopile it was therefore decided to use bismuth wire 0.1 mm. in diameter and silver wire 0.05 mm., which increases the radiation sensitivity closely to that of the element with bismuth wire 0.15 mm. in diameter and leaves the time of attaining temperature equilibrium about the same as that of the element having bismuth wires 0.06 mm. in diameter. The various elements, joined in parallel as shown in Fig. 4, D, reduce the resistance and increase the sensitivity. By having the units of closely the same resistance there will be but little shunting of the current generated.

In making the units, the individual elements are mounted in a row upon a glass plate, as previously described for the linear pile. The ivory support is then placed over the central line of receivers and the end wires are bent back against the side of this support (shown in Fig. 4, B, C) and attached thereto with boiled shellac or "Khotinsky" cement. The silver wires are then joined as shown in Fig. 4, C. The mounting for these ivory supports (Fig. 4, A) may be of brass and, for convenience in construction, may be circular as shown in Fig. 5. The slight adjustment of the ivory supports necessary in placing them upon this mounting is accomplished by means of slots and bolts as shown in Fig. 4 A, or by means of clamps as shown in Fig. 5.

In Fig. 5 is shown a surface pile made of three units, each consisting of 20 elements. The individual receivers are of tin 6 x 1 x 0.03 mm., and the total area is about 17 x 17 mm. Obviously the sensitivity to be attained depends upon the number of units, and this depends upon the patience one has in constructing such instruments.

The Rôle of Gelatine in the "Chemical" Development Process. A. P. H. Trivelli. (*Chem. Zentr.*, i, 958.)—The presence of gelatine increases the quantity of silver bromide that will be reduced by a definite quantity of developers, and retards the direct reduction of the fixed silver bromide, which gives rise to the developing film.

Subtractive Production of Artificial Daylight. H. E. IVES and M. LUCKIESH. (*Electrician,* lxvii, 297.)—In general, artificial illuminants differ from daylight by having an excess of red and yellow radiation in their spectra. Hence, by inserting a suitable screen in front of such sources, it should be possible to produce light of a color resembling daylight, and for many industrial purposes "artificial daylight" would be very serviceable, as it would facilitate correct color matching by artificial light. As daylight varies during the day, the aim is to attain average daylight. A combination of screens has been contrived reducing the various colors in the spectrum of the tungsten lamp to such proportions as to give a light very closely resembling daylight. A combination of cobalt blue and signal green glass, plus a gelatine film, colored with a suitable aniline dye, which weakens the intermediate yellow-green element, is found effective. Curves are given comparing the experimentally-determined transmission of such a screen with that theoretically ideal, and the resemblance is very close. An artificial "daylight window" is contrived on this basis.

Electric Steel Furnaces. F. DOUBS. (*Stahl and Eisen,* xxxi, 589.)—An Héroult furnace for 5 tons and one for 6 tons have been at work since 1909 and 1910, respectively, in a wire mill in Carinthia and a roller mill in Styria. Square electrodes caused trouble by burning unevenly, so cylindrical electrodes with water-cooled holders were substituted. The electric furnace can compete with the medium-size Martin furnace in the production of temper castings (iron to be annealed in an oxidizing atmosphere); but Martin furnaces would be more economical for producing soft steel on a large scale. Yet there are opportunities for electric steel furnaces in the Alps. The author, however, prefers three-phase Nathusius furnaces to the single-phase Héroult furnaces which require a rotary transformer. That the electrodes are imbedded in the hearth does not impair the strength of the Nathusius furnace.

Methane in Hungary. A. PÉCSI. (*Revue Scient.,* xlix, 6, 180.)—For some time it has been known that small sources of methane existed at different places in the great Hungarian basin. In some towns, such as Püspökladang, Arad, and Temesver, these natural gases are used for lighting, or for motive power in the factories. Recently large supplies of methane have been found in the Transylvania basin. The largest are at Kissármás, and in the vicinity of Marosvásárhely. Further search is being made under the direction of M. de Lóczy, director of the Royal Hungarian Institute of Geology.

SIMPLIFYING SOME THERMAL CALCULATIONS BY THE USE OF THE THERMAL OHM.

BY

CARL HERING, M.E.,

Consulting Electrical Engineer.

If a manufacturer is using a machine which does its work in a slow, intricate, round-about, complicated manner, necessitating that considerable attention be given to it, he would, if he were progressive, be very glad to adopt a new one, if it turned out exactly the same product but in a simpler, more direct, and more reliable way, with economy of labor and attention, and he would willingly scrap the old one, especially if the new one were presented to him. Yet when the machine is the man's own brain, and the work it does is to exert mental effort in performing calculations requiring thought and care, and involving at times great responsibilities, the average man will continue to work in the rut dug by his forefathers, rather than to adopt improvements that are offered to him gratis, which have for their object economy in brain work, or what may be called the conservation of mental effort.

As an illustration, a vast amount of such mental effort is being absolutely wasted daily by millions of people in Great Britain by the use of their senseless, antiquated, irrational but beloved £ s. d. We in this country could appreciate it, if we were to think for a moment of what a mental tax it would be to us, in our daily finances, to change back from our decimal system to the awkward, antiquated English one. Similarly, the people in the more progressive nations like Germany and France, who have adopted the decimal system in all their other measures, can use for other and really profitable purposes the vast amount of brain labor and mental effort which we in this country are wasting daily with our awkward and cumbersome system of weights and measures, which they look upon as being as absurd as we think the English money system is. It is no wonder, therefore, that such magnificent mental work issues from those more progressive countries in which man's brain is not hampered and fatigued by the wasteful mental brake which it has applied to it incessantly, as it is in this country and even to a still greater extent in England.

In an article in the February, 1911, issue of this journal, page 129, the writer made an analysis of systems of measures and called attention to numerous improvements that could be made with a view to economy in mental effort in performing calculations such as an engineer has to make daily. It was there shown that the physicist has the great advantage in using the so-called absolute or *c.g.s.* system, in which there is one, *and only one,* unit for each physical quantity, and in which nearly all coefficients and conversion factors drop out of the calculations because they are unity; and that it would be quite feasible for the engineer to benefit by the use of a similarly ideally simple system by merely adopting as his working units decimal multiples or fractions of the absolute units, as in fact the electrical engineer has done in his excellent brain-saving system of electrical units. It would even be of more importance to the engineer than the absolute system is to the physicist, because he has vastly more calculations to make, and they are often of greater importance, as mistakes in them in designing engineering structures may cost the lives of innocent people.

Although such means for economizing mental effort are offered to us gratis, the average man is like the manufacturer who prefers to continue to use antiquated machinery rather than to scrap it and accept the better one that he can obtain without cost. He complains that it is too much trouble for him to move away the old machine and set up the new one, as his more progressive neighbor does. The natural result is that the one gets the trade while the other is fossilizing. It is not surprising, therefore, that, in accordance with the law of the survival of the fittest, a progressive country like Germany, where the economy of mental effort enables that effort to be more profitably applied, is fast getting the world's trade from its neighbor who is burdened with a fossilized system of mental brakes in the shape of absurdly complicated, brain-robbing systems of measures, almost all of which we had the misfortune to inherit from England, and which we cling to as the unprogressive manufacturer clings to his antiquated, out-of-date machine.

Although it may, unfortunately, take us several generations more before we succeed in giving up our cumbersome systems of measures, and adopting the decimal systems, yet there are some directions in which we can save mental effort without parting with any of our beloved antiquities, namely, by adopting some new and rational units or measures where none existed before.

The purpose of the present article is to show how, by the adoption of a new unit for a quantity for which no unit has existed, the mental labor in a certain class of calculations can be greatly simplified and reduced.

In general, when no definite unit exists, we naturally refrain from using that quantity by adopting some round-about methods, or, when we must use it, we have to define a unit of our own—a home-made unit, as it were—which generally results in different writers giving their data in different units, thereby causing the waste of much mental effort by the one who desires to combine and use such data from different sources. In a recent case of this kind, an author of an otherwise excellent paper had made up such a home-made unit, quite different from all the others, in terms of which his valuable quantitative results were given, but had carelessly omitted to give the receipt according to which that complicated unit had been concocted, and it cost the present writer the best part of a day to work out its composition before the data became available, all of which mental effort could have been saved had the unit been described, or, better yet, had there existed a well-defined, recognized, international unit for measuring that quantity.

One of the groups of calculations in which no definite units exist for certain quantities is that concerned with the flow or transmission of heat by conduction, convection, and radiation. It therefore concerns such calculations as the thermal insulation of steam or refrigerating pipes, of electric and other furnaces, the transference of heat from the flames to the water in boilers, or from the flames or the arc of a furnace to the metal to be melted, the insulation of thermos bottles, the cutting of metals with flames, the repairing of broken metal machines by local fusion, etc.

For measuring heat energy itself, statically, plenty of units exist; too many, unfortunately: the large calorie, the small calorie, the B.T.U., the mongrel pound-centigrade unit, the joule, and the erg, some of which have several names; in name there exists a seventh, the "heat unit," which may mean nearly any of the others, according to the fancy of the writer, and is therefore meaningless unless defined by the user.

When a flow of heat is involved, that is, a rate of transmission of heat, the element of time must be introduced, and here there is again the choice of the hour, minute, or second, according to the fancy of the writer. Six heat units combined with three time units make eighteen possible units of heat flow, from among which different writers seem to delight in choosing that one which they think other writers have slighted. However, each one of this family of eighteen would be an intelligible unit for expressing a flow of heat if its particular make-up is clearly specified by its particular admirer.

Flows of heat through bodies are conducted, and they then meet with more or less resistance in that body, which resistance, for instance, is said to be about twenty or thirty thousand times as great through a piece of flannel as it is through an equal piece of copper. And as this thermal resistance varies so greatly and is of great importance, it becomes very desirable, and sometimes even necessary, to use it as a quantity capable of being measured, calculated, and specified; hence there should be a unit in terms of which this can be done. But no such unit existed, and the consequence is, as usual, that an author either evades using this quantity, or else makes up a unit of his own; this results in a great multiplicity of units ambiguity in their meaning, and, in general, much wasted mental effort on the part of the one who has to apply the data to practical cases. Some authors seem to take particular pleasure and pride in making up new composite units in such cases, and sometimes the only originality in an article is the invention of a different unit which no one else has cared to use.

Thermal resistances have in the past been generally avoided by using the reciprocals instead, namely, conductances (often incorrectly called conductivities, which are really specific conductances). But in by far the most cases in practice a flow of heat passes through several bodies in succession, that is, in series, as the electrical engineer terms it. Even in simple cases there are generally several successive contact resistances in series with that of the material itself, and these are sometimes extremely high; in fact, at times the most important of all, as in steam boilers, for instance, in which by far the largest part of the virtual thermal resistance is at the contact of the flames and the outside of the water tubes; this is so very great that the difference between the resistance of copper and iron tubes (about 4 to 1) falls into insignificance.

When heat or electricity flows through several bodies in series it is far simpler to use resistances in the calculations, instead of conductances; and when they are in multiple the reverse is the case. The former being by far the more general case, it is much more rational to use thermal resistances than the older and more common conductances. This is the first of the improvements which is here recommended for the purpose of economizing mental effort in such calculations.

But in view of the fact that conductances have in the past been used almost exclusively, let us consider for a moment the question of the units of conductance and conductivity. Such units are composite and must be made up, and this particular case is a good illustration of how each writer is apt to make up one of his own without the slightest regard for uniformity. Moreover, it seems that no one, until recently, has ever suggested a unit of conductance itself, but only of conductivity. Notwithstanding the convenience which the former would be, let us consider here only the latter.

A unit of conductivity is defined by a certain flow of heat through a specified cross section for a specified length, hence involves areas and lengths. For the latter the physicists usually take the square centimetre and the centimetre, hence they specify the heat flow through a centimetre cube; yet the inch is also often used, and until we have abandoned this irrational unit it is convenient to give conductivities in inch cube units also. Besides these two, some writers also use the metre cube, others the square foot combined with one inch thickness, etc.; in one noted case of an otherwise excellent article descriptive of some valuable research work, the author of it even introduced the inexcusable mongrel combination of one square metre area with one inch thickness. But assuming that there are only four sets of these linear and superficial units, then with the 18 different possible units of heat flow mentioned above this makes 72 possible units of thermal conductivity—enough for the most fastidious writer to choose from if he wants something different from what others use; something "original."

This absurd and deplorable state of affairs, and the waste of mental effort which it involves, led the writer some time ago to investigate the subject with a view to finding, if possible, that unit in each case which is at the same time the most rational and reduces the calculations to the least possible.

As stated before, the units used in the absolute system are those which bring nearly all coefficients to unity, hence involve no troublesome conversion factors. Hence, whenever we are in want of a new unit it is best to go to this absolute system, and, as the units in that system are often inconveniently small or large, to take some decimal multiple of them. This is what was very wisely done when our system of electrical units was devised, and those who enjoy the simplicity of electrical calculations should be thankful to our forefathers for their good judgment and wisdom.

A flow of heat is a particular case of the transmission of energy, the particular one in which the transmitted energy is in the form of heat, but as it may be transformed from or into other forms of energy, it is best, in the selection of a unit, to consider energy in general, and not only one form of it. The unit of energy in the absolute system is the erg, which is equal to the force of a dyne acting through a centimetre. The unit of time in that system is always a second; hence the absolute unit for measuring a transmission of energy of any form is an erg per second. This being inconveniently small for practical work, it has been decided, for electrical purposes at least, to make the practical unit ten million times as great, and this unit is known as the watt.

Hence the most rational unit for measuring a flow of heat is the watt. To say that the heat flow in a certain case is so-and-so-many watts means that the amount of heat is that which would be set free if that many watts were converted into heat, as in an electrical heater, for instance. Hence, if this unit were used, all coefficients and reduction factors would drop out (or be some multiple of 10), at least for all calculations with electrical quantities, such as electric furnaces or heaters, etc.

As a watt is a joule per second, the coefficients and conversion factors would also drop out in all our heat calculations if the tables of thermal constants were reduced once for all to joules. Specific heats, which are generally given relatively to water, would then be given by their true, absolute values in joules. But such a revolutionary change as that, which would involve the dropping of all four of our "home-made" units of heat, for which we seem to have such an affection, and using only the two natural or absolute ones, the erg and joule, is foreign to the present paper and need not be further discussed here.

Having found that the most rational unit of heat flow is the watt, and having decided that thermal resistance was a more generally useful quantity than conductance, the next question is, What is the correspondingly rational unit of thermal resistance? It is evidently that one which again reduces the coefficient to unity. The law of heat flow is, that the amount of flow increases in proportion with the temperature drop (which causes the flow) and decreases in proportion with the resistance (which opposes the flow); hence just like with electricity. This might be termed the thermal Ohm's law; or, represented by letters, if W is the heat flow, T the temperature drop, and R the thermal resistance, then $W = T/R$. It is in this fundamental law that the coefficient is to be made unity.

In the absolute system of units there is no temperature scale, as temperature has not yet been reduced to absolute measure. Hence, until it is, we are compelled to use some one of the artificial temperature scales, and among these the centigrade is certainly the more rational and the most commonly used in most countries and to a gradually-increasing extent in this country.

Hence, as T is to be in centigrade degrees and W in watts, it follows that the unit for the thermal resistance R must be so chosen that the coefficient in this law will be unity. Hence R must be made equal to that thermal resistance which will allow one watt to flow when the temperature drop is one degree centigrade; this is the unit that the writer has termed the thermal ohm, a name originally suggested by Dr. A. E. Kennelly, for thermal resistance, though for a quantitatively different unit.

Hence, when the physical property of a given body through which heat is flowing is stated in thermal ohms, and the temperature drop in centigrade degrees, the quotient of the latter by the former will give the heat flow in watts directly without any further reductions. It has therefore been reduced to the simplest possible kind of a calculation.

For calculations involving electric heat, such as those concerning electric furnaces and heating devices, nothing simpler could be desired, but even in other cases it will often be found to be simpler to make the calculations in thermal ohms and watts, and merely convert the final result back to the older and more cumbersome units, in which it may be desired.

The physical property of materials, called resistivity (specific resistance), as given in tables, is then stated in thermal ohms for one centimetre cube or one inch cube, and with the aid of these the total resistance of any given block of material is determined just as for electrical resistance, namely, by the usual formula $R = rL/S$, in which R is the total resistance in thermal ohms, r the resistivity in thermal ohms, L the length and S the section, centimetres or inches being used consistently throughout.

The use of thermal resistances as such, in calculations, is often a great convenience and time-saving device. For instance, in determining the insulating walls of electric furnaces the temperature drop is known, and so is also the allowable loss in the form of a percentage of the total input. The former divided by the latter then gives the resistance which the walls must have in thermal ohms. With the resistivities of the various materials and the inside dimensions of the furnace, the thickness of each layer of the different materials making up the total wall can then be calculated so that the sum of all the resistances is equal to that required. This would be an extremely tedious calculation to make with conductances. The temperature at the junction of any two layers can then also be readily calculated with the same formula; W and R being then the known quantities, T is equal to their product.

In the insulation of steam pipes the temperature drop from the inside to the outside is known, and the permissible loss in power (reduced to watts) is decided upon; their quotient then gives the total insulation resistance in thermal ohms, hence per foot or per inch of pipe. Knowing the resistivities of the various insulating materials, the thickness of each can then be readily calculated, hence their respective costs, which can then be properly compared. It may thus be found, for instance, that it is cheaper to use a thin layer of a better insulator than a thick layer of a poorer one, or the reverse; or perhaps that a combination of two layers is better. For thick layers over small pipes the outer layers count for much less than the inner.[1] Several such trial calculations would show to what extent the value of the steam energy which is being saved is worth the cost of saving it. In such cases the reduction to and from watts is made once for all, the simple Ohm's law being then available for the more numerous trial or comparative calculations.

For a certain limited class of simple calculations involving steam or fuel energy alone, when the physical constants are available in the best form for direct application, it may be more convenient to use the older method based on conductivities and without reducing to watts; but when anything different from the ordinary is involved, it will probably be found to be simpler to perform the computations in terms of watts and thermal ohms, and reduce merely the end results to the units desired, just as it is often simpler, in the more involved calculations, to reduce values to the metric system, perform the calculations in that system, and convert the end result back to our old units. It is also possible, of course, to establish other units of thermal resistance, based on the particular thermal temperature, time and length units, which one may be accustomed to using, by a method which reduces the coefficient to unity, similar to the one here used to establish the thermal ohm.

Another advantage of such a unit as the thermal ohm is that, being based on the absolute system, it is a rational one to which all values determined in other units could be expected to be reduced by the authors, hence it could be used as a sort of standard international thermal unit in terms of which all determinations can be readily compared, and from which they can readily be reduced to any other specific units desired; a sort of clearing-house for the 72 possible units of resistance.

Attention is here called to the fact that in not a few books and papers the heat flow and thermal conductivity units based on the gramme calorie per second, centigrade, and centimetre cube are claimed to be the absolute units. This is an error, although a very common one; this can be shown by the fact that they are incommensurate with the true absolute units. There is no heat unit in the absolute system; heat is energy, and the energy unit in that system is the erg and not the gramme calorie. The units recommended by the writer (watt and thermal ohm) are the ones which are the decimal multiples of the true and correct absolute units, and they are incommensurate with the so-called absolute units just described.

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[1] See an article by the present writer in the *Electrical World*, November 25, 1911, page 1303.

A table of about 150 values of the thermal resistivities of different materials, taken from various sources and reduced to thermal ohms by the writer, is being published in the December issue of *Metallurgical and Chemical Engineering.* The values in centimetre cube units range from about 0.24 to about 3 for the metals; 25 to 180 for various bricks and solid stones; and from about 250 to 5000 for granular or fibrous materials mixed with air. It will therefore be seen that the unit is of a convenient size.

A table of conversion factors for reducing the various units of thermal resistances, conductances, resistivities and conductivities to one another is given in the writer's paper on the thermal ohm, in *Metallurgical and Chemical Engineering,* January, 1911, page 13.

Density of Niton (*"Radium Emanation"*). R. W. GRAY and W. RAMSAY. (*Roy. Soc. Proc. Ser.,* H.84,536.)—The balance used to weigh the niton (RaEm) was sensitive to 2 micro-milligrams and acted on the same buoyancy principle as that of Steele and Grant, but certain modifications were introduced. Five experiments were made to determine the atomic weight of niton; the mean result was 223. The amount of helium produced by the niton and its products on complete disintegration to RaD was determined by weighing, and the result agreed closely with the disintegration theory, although about one-fourth of the helium had entered the walls of the weighing-tube and had to be expelled by heat and subsequently weighed. The experiments afford further proof of the disintegration theory on which the weight of niton should be 222.4 (Ra 226.4—He 4).

Temperature of the Sun. F. KURLBAUM. (*Preuss. Akad. Wiss. Ber.,* xxv, 541.)—By a spectroscopic comparison of sunlight with a standard lamp, a series of determinations of the solar temperature have been made. The mean result is given as 5730° abs. by the Holborn-Day scale or 6390° abs. by the Holborn-Valentiner scale.

MODERN USES AND APPLICATIONS OF RADIUM.[1]

BY

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WHEN Professor Roentgen discovered the Roentgen or X-Ray, it was generally believed that the powerful and penetrating rays emitted by the so-called Roentgen tube *were produced or emitted* by the bright fluorescence which constantly appeared when the Roentgen tube was in operation. This belief in the creation of these powerful rays by the fluorescence caused most of the physicists who were investigating this field to experiment with a great many fluorescent materials in order to determine whether similar powerful rays were emitted by any such materials. Among these investigators was Professor Becquerel, of Paris, who one day, after experimenting with some fluorescent uranium salts, not being able to finish his experiments that day, placed the uranium salts in a drawer of his desk. After several days, upon opening the drawer and seeing the uranium salts, he determined to continue his experiments. When he removed the uranium salts he saw that, by accident, they had been resting during this period upon a photographic plate contained in a securely-sealed envelope, such as is generally used for X-Ray and similar purposes. Becquerel then determined to develop this plate for curiosity's sake, and found to his great delight that the plate had been strongly affected by radiations of some kind. This led to further experimentation with uranium materials, leading finally to the discovery of what are now known universally as the Becquerel rays.

Madame Curie then took up the investigation of these uranium salts and soon found that pitchblende, the ore from which uranium is extracted, emitted the same radiations as the uranium salts, only in a far larger proportion. Madame Curie then obtained from the Austrian Government, which controls the

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[1] Abstract of a paper presented at the stated meeting of the Institute, held Wednesday evening, September 20, 1911.

Bohemian pitchblende mines, some of the refuse of the pitchblende ore after the uranium had been extracted, and she found that this refuse was far more radioactive than either the uranium or pitchblende themselves. This convinced Madame Curie that pitchblende contained something which emitted powerful rays, apparently independent of the uranium. Further investigation led to the discovery of what Madame Curie at that time believed to be a new element, which she named Polonium, after the country from which she came. This Polonium emitted a very large quantity of radiations, which, however, were of very low penetrating power. It has since been found by Prof. Ernest Rutherford, at that time of McGill University, now of Manchester, that Polonium is not a primary radioactive element, but simply a disintegration product of the radium emanation, to which I shall refer later.

Madame Curie continued her investigations and soon found that the pitchblende refuse contained still another element which emitted the same radiations as Polonium, besides various other radiations of far greater penetrating power. This element Madame Curie named radium.

Experimentation at first led physicists, especially also Madame Curie, to believe that radium emitted three kinds of rays, which, for convenience, were called the alpha, beta, and gamma rays. The alpha rays are of very low penetrating power. They are absorbed even by tissue paper or very thin sheets of aluminum. The beta rays, which greatly resemble the Goldstein or Cathode rays, are of far greater penetrating power. Lastly, the gamma rays, which greatly resemble the Roentgen or X-Rays, are of tremendous penetrating power. I personally have been able to obtain fine photographs with these rays through twelve inches of steel.

The study of this new element was then universally taken up by physicists all over the world, and especially have the investigations of Prof. Ernest Rutherford been exceedingly fruitful. Rutherford soon found out that radium itself emits but one radiation, and that is the so-called alpha ray. But, besides this radiation, radium emits a certain gas which is called the emanation. These emanations were found to decay rapidly, and while decaying form a new product, which product also disintegrates or decomposes and in doing so forms another product, which likewise is subject to the same change, and so on. The various disintegration products themselves emit certain radiations, and the process of this disintegration, as determined by Rutherford, is as follows:

Radium, as stated before, emits the alpha rays, which in reality are small particles of matter that can be detected when the naked radium is exposed to a zinc sulphide screen, as the bombardment of the screen by these particles, which travel at a remarkable velocity, produces scintillations which look like millions of shooting stars or sparks under a magnifying glass. Through the constant giving off of particles the radium atom gradually breaks up, but this is so slow that only one-half of the atom is broken up in about 1,300 years. Besides these alpha particles, radium emits a certain gas, which, as the writer has stated before, is called the emanation. The emanations are very unstable, one-half of them breaking up in about 3.8 days. The emanations themselves emit only alpha rays, and, as said before, rapidly decay, and while decaying form a new disintegration product, which Rutherford has named radium A. Radium A is the most unstable of all the emanation disintegration products, one-half breaking up in about three minutes. Radium A emits only alpha rays, and when breaking up forms another product, which is called radium B. Radium B emits no rays and is transformed in twenty-six minutes, whereby is produced radium C, which is the most remarkable of all the disintegration products, for radium C emits all three kinds of rays, namely, the alpha, beta, and gamma rays. Radium C is also transformed, and during this transformation the alpha particles which are emitted are expelled with much greater velocity than the alpha particles of the other radium products. These alpha particles are absorbed only after traversing 7 cm. of air, while the alpha particles of the other radium products are never able to penetrate more than 4.8 cm. of air. Besides these alpha particles, the beta and gamma rays are emitted, which are of very much greater penetrating power. Radium C, when decomposing, forms a radioactive residue, which is called radium D. Radium D is far more stable than the other radium products, but it does not emit any rays. Radium D also decomposes and forms radium E, which emits only beta and gamma rays. The life of radium E is short, and its disintegration product is radium F. Radium F is the final radioactive product of radium. It is an element of high atomic weight and is identically the same product as that which Madame Curie discovered at first and named Polonium. It is also the same product which Professor Marckwald, of Berlin, discovered and named radio-tellurium. Radium F emits only alpha particles, but a far larger quantity of these than is emitted by any of the other radium products. Radium F is half transformed in 143 days.

If a quantity of radium emanations is left in a glass tube for some time, the glass will be covered by a radioactive deposit which can be dissolved in diluted H_2SO_4. If this solution is kept for a long time, say about a year, the activity of same will be found to have steadily increased. If polished bismuth discs are dipped into such a solution, this radium F may be deposited upon them electro-chemically, and, upon removing the discs, will give off only the alpha rays but no trace of beta rays, and this very fact led Marckwald to believe that he had discovered a new element, which he called radio-tellurium.

Besides radium, there have been found other radioactive elements, especially thorium. Thorium is the element from which the so-called Welsbach gas mantles are made. Another radioactive element has been found which is known as emanium; it has been named emanium on account of the great quantity of emanations it emits.

As previously stated, radium is found in pitchblende, the ore from which, in Bohemia, the uranium is extracted. Uranium is used very extensively in the manufacture of Bohemian glassware. After the uranium had been extracted from the ore, the so-called refuse was thrown away, and only since the discovery of radium has this refuse become an extremely valuable product.

However, radium does not appear only in pitchblende, but it appears in any ore that carries uranium, as radium itself is only a product of the decomposition of uranium, and the quantity of radium which is contained in the ore is in direct proportion to the quantity of uranium contained in that ore and can be correctly measured thereby. We have pitchblende in the United States, and it is found especially in Gilpin County, Colorado. Carnotite is also found in Colorado and in some other States. Both of these minerals carry large quantities of uranium, and consequently radium. Furthermore, minor quantities of radium have been found in the so-called monazite sands of North and

South Carolina. These are the same sands from which also the radioactive element thorium is extracted.

When radium was first introduced to the scientific world, it appeared as a grayish-yellow powder, in small, irregular crystals, and on account of its tremendously high cost was contained in small, hermetically-sealed glass tubes or vials. It must be remembered that radium itself emits only the alpha rays and emanations. The emanations and their subsequent disintegration products also give off alpha rays, and, later, beta and gamma rays. The alpha rays are of exceedingly low penetrating power and the emanations are of practically no penetrating power; but of all the radiations given off by radium and its subsequent disintegration products fully 95 per cent. consist of the alpha particles, whereas the remaining 5 per cent. consist of combined beta and gamma radiations. As radium formerly was contained only in hermetically-sealed glass tubes, all the alpha radiations, all the emanations, and even a part of the beta radiations were absorbed by the glass tube, and therefore when radium was applied in such tubes only a very small percentage of its total radiations, that is, a part of the beta rays and the gamma rays, could be utilized for physiological and other purposes. This led the writer, after due experimentation, to invent aluminum containers, that is, small containers of exceedingly thin aluminum sheets, which could be hermetically sealed by a suitable device. These containers had the advantage over the glass tubes in that they would permit all of the beta and all of the gamma rays to penetrate them; but even these extremely thin aluminum containers would absorb all the emanations and all of the alpha rays or particles. At that time it was despaired of ever being able to utilize the alpha rays and the emanations as valuable therapeutic agents. After long experimentation, and knowing and appreciating fully the importance and necessity of obtaining radium in such a form that access could be had to the emanations as well as to the alpha radiations, and especially considering the fact that even in naked radium we are able to utilize only those alpha radiations and emanations which are emitted by the direct outside layers of a radium particle, as those emanations and alpha radiations emitted by the under layers are unable to penetrate the upper layers, and knowing that for the utilization of these alpha particles and emanations the radium to be utilized would have to be with practically no under layers, the writer succeeded in finally constructing what are now known as "radium coatings." Radium coatings are manufactured as follows:

Radium is dissolved in a suitable solvent. This suitable solvent must of necessity vary in accordance with the substance which is to be coated. Thus, if a metallic substance is to be coated, the solvent should contain a certain proportion of an acid which is able to affect the surface of the material to be coated. If celluloid (which the writer preferably employs) is used, the solvent should contain such ingredients which are capable of softening and affecting the surface of the celluloid, and for this purpose the writer employs largely ether, wood alcohol, acetone, amyl acetate, etc. After the radium has been thoroughly dissolved in these solvents, the proper dissolving of which requires considerable care and experience, as the slightest amount of residue would entail a comparatively large financial loss, the material to be coated, usually either rods or discs, is dipped into the solution. Or, if dipping is not advisable, that part of the material which is to be coated is covered with a small quantity of the radium solution by means of a pipette. As stated before, this radium solution contains, dissolved therein, the radium usually in the form of either radium bromide or radium chloride of varying activities. Naturally the radium solution should be spread as evenly as possible upon the surface to be coated. Then the solvent is allowed to evaporate, which leaves the radium spread in a thin film all over the article to be coated. Since in the case of celluloid the solvent has the tendency to soften and dissolve part of the surface of the article, the deposited radium is thoroughly imbedded in the surface, whereby is fulfilled one of the principles desired, namely, to produce practically nothing but a surface of radium with as little radium as possible in underlying layers. However, if radium were used in this form for physiological purposes, it would be of very little value, for if these radium-coated rods or discs were brought in contact with any liquid or would be inserted into a diseased part and come in contact with the blood or juices of the human or animal body, the radium would completely dissolve and it would cause a complete loss of the material. It was therefore necessary to protect the radium film against loss through solution or mechanical friction, etc. This, however, was a very difficult problem, because of the fact that the main object was to obtain full access to the alpha radiations and the emanations, for if the writer had simply coated these so-produced instruments with a protective coating the alpha radiations and the emanations would certainly have been absorbed by the coating, owing to their extremely low penetrating power. It therefore was necessary to construct a coating which would answer both purposes, namely, be thin enough so that the alpha particles and the emanations could penetrate same, and at the same time be tough and protective enough to protect the radium filament from solution in the liquids with which it might come in contact and from mechanical destruction by friction, etc. The writer finally succeeded in doing this by gradually applying coatings of specially-prepared collodion solutions. These collodion solutions must vary in accordance with the material which has been coated with the radium, the main substance being so-called gun cotton dissolved in alcohol, amyl acetate, ether, etc., to which must be added various other ingredients. The writer finally succeeded in obtaining a coating that provided an absolute protection to the radium film and at the same time was sufficiently thin to permit the alpha radiations and the emanations to penetrate it. This penetration of the thin coating was readily proven as follows: since the alpha radiations are readily visible to the eye when they are brought in contact with zinc sulphide, whereby they produce scintillations, as is beautifully demonstrated in the Crookes spinthariscope: the same scintillation effect took place when the coated rod or disc was placed upon the surface of a zinc sulphide screen and was observed under a fairly good magnifying glass in the usual manner.

That the emanations are able to penetrate these coatings was proven in the following manner:

A rod, properly coated and protected, was placed within a glass tube, which was fairly well closed and sealed at both ends by rubber stoppers. After this coated rod was left in the glass tube for several hours (preferably twelve to twenty-four hours) a certain quantity of emanations collected within the tube. When, therefore, an air current was slowly forced through the glass tube it carried the emanations with it, and the presence of the emanations was proven by means of an electroscope.

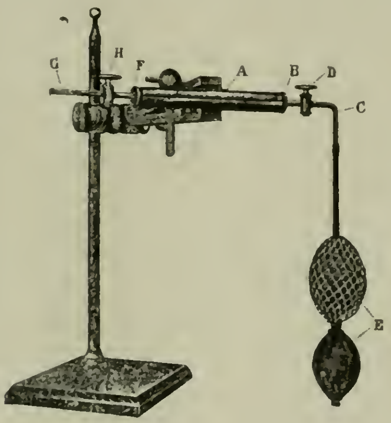
The method of measuring radioactive materials by an electroscope depends upon two well-established principles: first, that like electricity repels; secondly, that radium rays as well as radium emanations ionize the air. Ionization of the air means that the air is made a good conductor of electricity, as dry air otherwise is a non-conductor of electricity.

In the case of the Braun electroscope, an aluminum rod is suspended in a metallic case, which, for convenience, is closed off in the back and front by glass. This aluminum rod is suspended in this case by means of a piece of amber surrounded by hard rubber, both of which are non-conductors of electricity. Suspended and well balanced on this aluminum rod is an aluminum needle which moves very freely. At the lower end of the aluminum rod is an aluminum scale. When the suspended aluminum rod is charged with electricity, be it positive or negative, this electricity will instantly be conducted into the aluminum needle, and the aluminum rod and the aluminum needle will repel each other. However, only the aluminum needle can move, and will ascend the scale and will remain there until the electricity contained in the aluminum rod and the needle escapes, which escape would be extremely slow in a perfectly dry room. If we now bring radium or radium rays or emanations in the vicinity of the electroscope, these will ionize the air surrounding the electroscope and cause the electricity in the suspended rod and needle gradually to escape. The more powerful the radium is, or the larger the quantity of radiations and emanations given off, the quicker will the air be ionized, the quicker will be the discharge of electricity, and the quicker also will be the descent of the needle down the scale. By the rapidity of the descent of this needle is measured the quantity of radium or the radioactivity at our disposal.

The emanations should collect within a glass tube in which the coated rod has been contained for some time, if the writer's theory is correct that these emanations penetrate the coating. An air current blown through such a glass tube carries with it the stored-up radium emanations, and by bringing these emanations or the air charged with the emanations in contact with the electroscope the electricity contained therein always readily escapes through the ionized air and the needle of the electroscope falls more or less rapidly.

A still more efficient means of proving that the emanations penetrate the coating is by spreading the radium solution on the inside of a tube. For such purposes the writer uses preferably celluloid tubes, internally coated with a thin radium film having the same protective coating as described before. The tube is closed by means of rubber stoppers with glass stop-cocks, and all the emanations collected within this tube will follow an air current if forced through it.

In the accompanying illustration, *A* is the celluloid tube which is coated on the inside with the radium filament and protected by the protective coating. *B* and *F* are the rubber stoppers closing off the tube at both ends. Inserted in the holes of the rubber stoppers at both ends are the glass tubes *G* and *C* with shut-off cocks *D* and *H*. These cocks remain closed when the tube is not in operation, so as to permit the gaseous emanations to collect within the tube. Then, when it is desired to utilize the emanations, the rubber bulb *E* is inflated, the glass cock *D* is opened wide and the glass cock *H* is opened very gradually. The air from *E* is forced through *C*–*D* and through the tube *A*, out through *H*–*G* and carried wherever required.



If the writer's theory is correct and the emanations can penetrate the protective coating, these emanations, as stated before, collect within the tube. Then when the air is blown through the tube it carries with it the emanations. When this so-charged air is permitted to strike the top of the electroscope, the surrounding air becomes ionized and the electroscope needle descends, making it a very simple but conclusive experiment.

Thus, where formerly a glass tube containing a fairly large quantity of radium was required, which was very expensive indeed, we can obtain, by means of these coatings, the same, and even far better, results with only a small proportion of the quantity of radium formerly required. Furthermore, we have access now to all the emanations and the radiations for physiological or any other purposes desired.

The writer wants to direct attention to the following: If the beta and gamma rays, as has been asserted, are those of the greatest influence for physiological purposes or in the treatment of diseases such as cancer, lupus, etc., we must remember that these radiations are produced only by the disintegration of the radium emanation. If we now are able to take a rod or disc or any other instrument properly coated with radium and insert this into the diseased part, the emanations, whose disintegration produces these rays, will, instead of escaping into the tube and there being absorbed, now escape into the diseased part, to be retained there, to disintegrate there, and their subsequent products to produce these beta and gamma rays. Not only will these beta and gamma rays act upon the diseased part while the instrument is being applied, as was the case with the glass tube, but the radium emanation will be retained within the tissues, will continue to disintegrate, form its disintegration products, and continue to act upon these diseased parts.

An extensive series of experiments has been conducted by Prof. C. Stuart Gager, formerly of the Department of Botany, Columbia University, and now of the University of Missouri, to determine the effect of radium rays and emanations on plant life, and especially cell-formation. He has shown conclusively that in certain forms and under certain conditions radium rays, and especially the emanations emitted from a coated tube, are able to retard the growth of plants and cell-formation. Under other conditions, he very largely increased the growth as well as the cell-formation, all depending upon the various methods employed.

One important factor has to be considered in connection with these radium coatings, and that is the following: It is a well-known fact that the waters of the famous mineral springs, especially those of Europe, have certain healing and beneficial qualities. It also has been established beyond a doubt that if these waters are transported their healing and beneficial qualities are almost entirely lost after a few days. It now has been demonstrated that all of these well-known waters and springs contain more or less radioactivity, that is, not primary radioactivity by having a radioactive material dissolved therein, but what is called secondary radioactivity, such that has been imparted to these waters by having them charged with the gas or the emanations emitted by radium. After having proven this beyond a doubt, it has been the aim of a great many of our foremost investigators to artificially produce waters which would contain emanations absorbed therein. For this purpose the celluloid tube coated on the inside with radium has been used very successfully, and it is a matter of very simple experimentation to prove the efficiency of this device and furthermore to prove the contents of radioactivity in such waters. All that is required is that the air, by means of a rubber bulb, be forced through the tube which has remained closed for several hours, and the escaping air which has been charged with emanations allowed slowly to ooze through a column of water, which should be partaken of as quickly as possible. The writer has personally seen some very remarkable and beneficial changes produced in cases of a most desperate nature.

The celluloid tube coated on the inside also has been used with great success in the treatment of throat and lung affections, the patient being required once or twice a day to inhale the air which slowly passes through the tube and which is charged with the emanations.

The writer also has succeeded in applying the radium coatings to microscopic slides. A small part of the slide is coated with the radium solution and, after evaporation of the solvent, is coated with a collodion especially prepared for this purpose. These slides have proven very efficient and of importance for biological investigations, as they can be conveniently placed under the microscope. Bacteria, cell-formation, etc., can be placed upon them, and thus the effects of the radium rays and emanations upon various microbes and cell organisms can be conveniently studied under the microscope.

In a great many cases it has been found impossible to apply the radium either in the form of coatings or in a tube. This occurs because of the seat of the disease and the necessity of repeated treatments. In order to provide for such cases, the writer has devised what is known as radium gelatine. This is a sterilized solution of a gelatine which contains a small quantity of radium and which will coagulate when it becomes cold. However, before becoming cold, it is charged with as large a quantity of emanations as possible. This coagulated solution is heated several times, thereby liquefying it, and each time it is again charged with emanations, so that there is finally obtained a radioactive product which contains primary as well as secondary radioactivity. This gelatine is injected into the diseased parts in liquid form or is inserted by means of tampons, etc. Experience has shown that it is readily absorbed by the surrounding diseased tissues, and the radium rays, the decaying emanations, and the disintegration products are thus brought into play upon these tissues.

Steam Engines. H. HORT. (*Zeit. Ver. Deutsch Ing.*, lv. 943.)—This is a research on the properties of various volatile fluids which may be used, in conjunction with steam, in binary heat engines. The fluids mentioned are nitro-benzol, ammonia, sulphurous acid, and so on. The paper contains diagrams which illustrate the results obtained.

Babbitt Metal. C. H. CONGDON. (*The Metal Industry*, ix, 9, 393.)—The rise in the price of tin has caused a rise in the price of Babbitt metal, which contains from 80 to 90 per cent. tin, and of solder, which usually contains 40 to 50 per cent. tin. Some smelters, instead of raising the price of tin, substitute lead for more or less of the tin, ranging from 5 per cent. to 30 per cent.

Distillation of Tin in Vacuo. E. TIEDE and F. FISCHER. (*Ber.*, xliv, 1711.)—Tin was distilled in vacuo by placing a boat containing tin in a small electric furnace, which was placed within the distillation tube. This tube was made of glass, was kept cold by a stream of running water on the outside, and was connected with a vacuum pump. The first portion of the distillate had a brass-yellow color, due to the presence of sulphur. It was found possible to prepare tin from pure stannic chloride, which did not give this yellow sublimate unless it had been exposed for some time to the air of the laboratory.

A PRACTICAL APPLICATION OF FLUORESCENCE IN TESTING OILS FOR INDUSTRIAL PURPOSES.[1]

BY

ALEXANDER E. OUTERBRIDGE, Jr.,

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It has been my custom, since my appointment to the Chair of Metallurgy of this Institute, to open the annual session of the section with an address on some topic allied to the art. I hope to be able to show that in speaking to you on the testing of oils I am not, as would appear, diverting from that custom, my subject having a close connection with the metallurgical art as practised in the industrial foundry.

Those of you to whom the process of casting metals is familiar know that in the operation of molding considerable attention has to be given to the production of the "core"—that part of the mold which forms the hollow portions of the casting. In cylinders for internal combustion engines, or in locomotive injectors, etc., the interior of the casting is by far the more important part, and the accuracy of reproduction of this from the mold depends, of course, mainly on the excellence of the cores used. In view of the significance of the factor, core-making is, and has always been, regarded as a distinct and separate branch of the art of molding.

Cores were formerly all made by "ramming" a mixture of sand and such adhesive materials as clay, flour, molasses-water, or other constituents into a "core-box" of suitable configuration, thereby producing a compacted mass that could be removed from the box without injury. The "green"-core, as this was termed, was transferred to an oven, where it was slowly baked until hard. In this condition it was ready for insertion in the mold.

This method of core-making is still in universal use for large work, though for smaller cores a radically different process has come into vogue. A kind of quicksand is prepared by intimately mixing, in a suitable machine, beach or bar sand (called by molders "sharp-sand") and some vegetable oil (preferably linseed oil) in the proportion of from 30 to 100 parts of sand to one part of oil. The mixture, being mobile, is poured into the core-box to well fill the latter, and the excess is simply scraped off with a straight edge drawn across the top of the box. Provision is made for taking apart the latter and leaving the fragile core on an iron plate on which it can be transported to the core-oven without injury.

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[1] Abstract of address to the meeting of the Metallurgical Section, on Thursday evening, October 26th, 1911.

These oil-cores so produced are not only far cheaper than "rammed" cores—they are made by unskilled labor in a fraction of the time taken to make rammed cores by skilled labor—but are, moreover, extraordinarily tough when baked, and are impervious to moisture. They require no "venting," as but little tendency to form gas is manifested on pouring the metal.

In consequence of these advantages, the adoption of this method of making cores has during recent years notably increased, so that, at the present time, large sums are being spent annually by industrial concerns in the purchase of oil for their production.

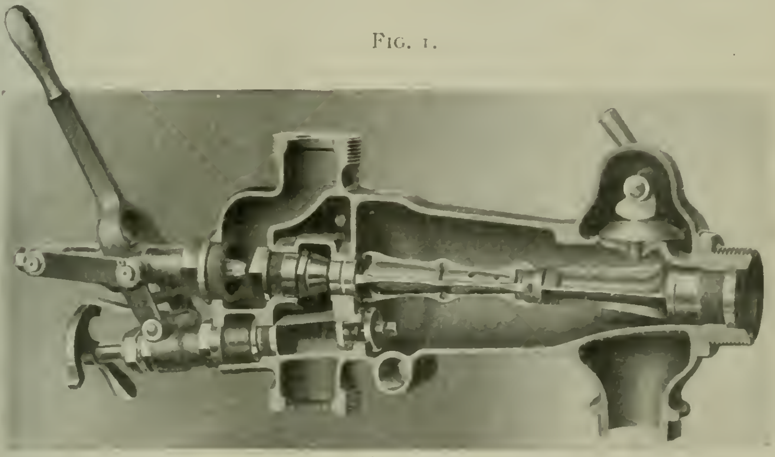
It was already stated that the best binder for making oil-sand cores was linseed oil. In the last few years the price of this has risen from 50 cents to $1 per gallon. "Soya" oil pressed from beans grown in enormous quantities in China has been found an excellent substitute. The cost of this is about 60 cents a gallon for fine grades. The very best substitute for linseed oil is, however, said to be crude whale oil, which costs about the same as "Soya" oil, although its use is objected to on account of the unpleasant odor emanating from the core-ovens during the operation of baking. Cottonseed oil has been used, but, as a large proportion of oil to sand is required, no economy results.

The high cost of the fine grades of these vegetable oils has brought about the introduction of so-called "core-oils." These usually consist of linseed oil as a base and mineral or resin oil, or both. Experience has shown that the presence of the latter "non-drying" oils materially affects the cores, renders them brittle and subject to rapid deterioration, and is, therefore, undesirable. Hitherto, however, no method except the costly one of chemical analysis, usually impracticable in industrial plants, has been available for detecting their presence and amount in oils supplied.

The method about to be described to you was some months ago tried out and put into practice at the works with which I am connected. I also had the honor of demonstrating it before the American Society for Testing Materials[2] last June at Atlantic City.

The basis of the method is that hydrocarbon oils (incorrectly termed "mineral") and resin oils exhibit, under the rays of reflected light, the phenomenon known as fluorescence and termed in this connection "bloom," while vegetable oils exhibit no such fluorescence or "bloom." All these oils appear of their natural color in transmitted light.

FIG. 1.



Locomotive Injector.—Bronze casting cut to show intricate cavities and thin partition walls made with oil-sand cores.

In both mineral and resin oils the degree or intensity of bloom depends on the degree of refinement of the oil, and is generally in proportion to its natural color. Mineral oil exhibits, however, green fluorescence, while that exhibited by resin oil is blue.

Fluorescence is the property inherent in certain substances of becoming self-luminous on exposure to "ultra-violet" or

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[2] *Proceedings of the Society*, vol. xi, 1911.

"actinic" rays of light. Such rays are present to some extent in daylight, and under this the phenomenon can be observed to a certain degree.

As the result of investigation using the various forms of electric light, such as that given by carbon or tungsten filament lamps, by Cooper-Hewitt mercury vapor tubes, by ordinary and flaming arcs and by enclosed arcs, it was found that the intensity of bloom in bloom oils was particularly increased under the rays of the latter. The utilization of this observation in the practical detection of adulteration and quantity of adulteration in vegetable oils forms the subject-matter of this paper.

When it is remembered that the method of chemical analysis for the detection of a small quantity of impurity is very costly, that the method of studying fluorescence by means of quartz prisms and lenses mounted in a spectroscope has the same disadvantage, and that, moreover, skilled manipulation by highly-trained observers is essential to both, the significance of the simple method under consideration becomes at once apparent.

That the method is efficient so far as discrimination between nature of oils is concerned is shown by the fact that under the rays of the enclosed arc neither linseed oil, "Soya" oil, corn oil, cottonseed oil, China bean oil, China wood oil, nor, in fact, any of the vegetable oils, show the slightest trace of fluorescence. On the other hand, all mineral and resin oils, except the very volatile products of petroleum, such as gasolene and petroleum ether, show marked bloom, as also do samples of so-called No. 1 and No. 2 lard oils, while pure white strained lard oil is seen to be free from bloom. This latter introduces the question of oleic acid in lard oil said to be in itself fluorescent, and the method may furnish a novel means of determining the amount of such acid present.

The slight fluorescence of lard oil differs in appearance from that of mineral or resin oil, hence adulteration of lard oil by either of the latter may be detected by the method.

Processes of chemical treatment are supposed to have been discovered to "de-bloom" mineral and resin oils, thus facilitating their use as adulterants of the more expensive vegetable oils. There is at the present time a large trade in such oils.

Samples of de-bloomed oils of various grades and colors were obtained. Such exhibited no fluorescence in bright sunlight or in the light from the ordinary arc. On exposure to the rays from the enclosed arc they are, however, seen to possess distinct bloom.

A metal-cutting compound now being sold as "mineral lard oil"—its name indicates its composition—shows strong fluorescence. Under the enclosed arc kerosene is seen to become a beautiful blue color. Cheap fuel oil from the storage tank becomes quite opaque and entirely self-luminous. Resin oils of different grades and resin oil mixed with turpentine exhibit the phenomena.

Pure linseed oil costing $1.10 a gallon, and Pennsylvania fuel oil costing 3 cents a gallon, diluted with a small quantity of kerosene, are seen to be indistinguishable under transmitted light, while under the arc the contrast between them becomes very forcible.

The demonstration shows that no misstatement is made in saying that any kind of mineral or resin oil can be distinguished from any kind of vegetable or animal oil. Further, if the latter oils be adulterated with the most minute quantity of the former the impurity can at once be detected by the method, and in many cases the nature of the adulterant can be at once stated.

The quantity of adulteration present is determined from the intensity of bloom produced in oils free from bloom; the nature of the impurity from the green or blue color.

By preparing a set of standards of pure linseed oil with one-tenth, one, two, three, four, etc., per cent. adulteration with mineral or resin oil, in glass test-tubes mounted in a suitable frame against a dark background, a means is provided whereby the proportion of impurity in any adulterated linseed oil can be quickly determined by color comparison on exposure to the enclosed arc. Such standards furnish a "scale of fluorescence" somewhat similar to the well-known carbon color-scale used in steel foundry laboratories for rapidly determining by color comparison the proportion of carbon in an acid solution of steel.

These standards, having linseed oil as a base, may be used for the examination of any adulterated vegetable oil, but for lard oil a special set of standards with pure lard oil as a base must be made up.

A set of standards was prepared with so-called bloomless mineral oil as the adulterant for the purpose of readily detecting the presence and amount of such adulterant in any sample of vegetable oil.

Detection of the presence of a combination of mineral and resin oil adulterants in one sample of vegetable oil is rendered possible by virtue of the color of bloom imparted, although the "quantitative" determination of the amount of adulteration is at first difficult.

In cases, too, where the adulteration of vegetable oils exceeds ten per cent. it is necessary, in order to correctly estimate the exact amount of it, to dilute the sample with a known quantity of the pure oil, quantitatively determine the adulteration in this diluted oil, and thus in the original sample by calculation. This procedure is necessary from the fact that comparison of color value is impossible when the bloom is of such intensity as to produce apparent opaqueness.

In practice it has been found advisable to prepare standards with fluorescent oils of different grades as adulterants. Crude mineral or resin oils are much darker in natural color than refined oils from them, and the color of the oil by transmitted light is often a guide to the nature of the adulterant employed, and consequently furnishes an indication of the proper set of standards necessary in making the "quantitative analysis" by comparison of fluorescence.

In conclusion, this practical application of fluorescence to the testing of oils for industrial purposes is not, of course, intended to furnish a method to supplant chemical analysis, but merely to afford a means of rapidly ascertaining whether an expensive vegetable or animal oil is or is not free from suspicion of adulteration. At the same time, however, the method is so sensitive in the case of mineral oil adulterants most commonly used as to furnish a correct indication of the amount of adulterant present. The fluorescent tint here exhibited is one so characteristic that after a little practice it cannot be confused with the slight fluorescence of some oils in which no mineral oil is present.

The fluorescent test for kerosene adulterant is, however, not sufficiently sensitive to be of practical value, for the reason that kerosene is not of itself fluorescent enough to tinge other oils to which it is added in small amounts.

In presenting this new method of testing oils without the necessity of chemical knowledge or experience criticism is invited, for only by such can any faults that may have been overlooked be developed, or any advantageous features that may have escaped observation be brought out.

COMMUNICATED DISCUSSION.

MR. NEMZEK: I have listened with considerable interest to the excellent address made by Mr. Outerbridge, and feel the same as I did last June at Atlantic City when I had occasion to hear this talk given before the American Society for Testing Materials; namely, that it is a valuable addition to the analysts' methods for the examination of oils.

Since I first heard the talk and witnessed the demonstrations that you have just seen I installed an enclosed arc lamp and made some experiments in an attempt to establish the value of the method for quantitative purposes. If it proved accurate it would be a boon for my laboratories. I found that the fluorescence or "bloom" is greatly magnified, but apparently the value of the method was limited to this fact. The great number of resin and mineral oils makes impossible accurate quantitative results. The range of color in the samples showing fluorescence varied from a light blue through the purples and extended into dark greens. It would be necessary to have a set of standards made up from each kind of oil on the market, and, in a specific case, inside information as to the nature of oil used for adulteration. Unless this was available, any consistency regarding quantitative results is impossible.

In making up tests for quantitative analysis by using different kinds of mineral oils it was possible in one case to obtain what appeared to be a two per cent. adulteration, when in reality thirty per cent. of a mineral oil was present. In another instance a thirty per cent. adulteration with a so-called de-bloomed oil showed only two per cent. by this test. This merely illustrates the wide variation in bloom created by different mineral oils.

Furthermore, about fifteen per cent. of the samples of pure linseed oil examined showed marked fluorescence; about 70 per cent. of boiled linseed oils showed a characteristic bloom;

several samples of spirits of turpentine gave affirmative results, and 60 per cent. of wood turpentine samples gave marked color reactions.

These reactions are easily explained in the case of the turpentines, but no real reason is found in the case of the linseed oils. The analysis showed them to be pure. The one possibility is that a drop or two of mineral oil from machinery used in the manufacture of the oil has contaminated it. This is a remote instance, but if true would indicate that the method will not meet practical application, as it would prove misleading.

From the above it can readily be seen that this test in the hands of an experienced operator would prove dangerous and lead to serious complications.

There has come to my attention information which indicates that one of the Government laboratories has lately issued a bulletin on the subject of tests for fluorescence of mineral and resin oils, which substantiates in substance some of the remarks I have made.

As a matter of information I might say that we have no trouble in obtaining pure linseed oils. If adulteration exists it is not so much present in the form of mineral or resin oils, but rather some semi-drying oils the character and percentage of which it is a difficult thing to determine, even by chemical analysis.

I do not desire to detract from the very valuable contribution to science that Mr. Outerbridge has given us by his interesting discourse, and I merely state these facts to bring to your minds some features in connection with the method that may prove of help to you, and incidentally show the necessity of carefulness in exploiting a new test of this kind.

PROFESSOR OUTERBRIDGE: I have already said that I welcome the fullest discussion and criticism of this novel method of detecting the presence of mineral and resin oils in other oils, and I am pleased to note that the gentleman who has just spoken regards this process as "a valuable addition to the analysts' methods for examination of oils."

I, myself, have only ventured to regard it as a *substitute* for analysts' methods in cases where such slow and tedious processes are not available or practicable in foundries and workshops.

Mr. Nemzek says "in making up tests for quantitative analysis by using different kinds of mineral oils it was possible in one case to obtain what appeared to be a two per cent. adulteration, when in reality thirty per cent. of a mineral oil was present." He doubtless refers to kerosene as the adulterant in this case. Had he used thirty per cent. of gasolene or petroleum ether he would have found no fluorescence imparted to the linseed oil, for the highly volatile products of petroleum are not fluorescent.

Kerosene when added even in very small quantity to other oils is readily detected by its odor, and if added in considerable amount renders the mixture extremely limpid and suspiciously light in color. I do not regard kerosene as a dangerous adulterant for these reasons.

Mr. Nemzek says "in another instance a thirty per cent. adulteration with a so-called de-bloomed oil showed only two per cent. by this test." The comparison is evidently made with a sample containing two per cent. of highly fluorescent mineral oil, not de-bloomed.

A casual inspection by transmitted light would prevent such a palpable error, as I have already explained. Furthermore, there is an appreciable difference between the fluorescent tints of de-bloomed oil and ordinary mineral oil. Finally, I may say that I have boiled several samples of pure non-fluorescent linseed oil until they became quite dark in color and have not observed the development of fluorescent tints that could be mistaken for the characteristic bloom of mineral oil when examined under the rays of an enclosed arc lamp.

I fully agree with Mr. Nemzek's concluding remarks and was careful, "in exploiting a new test of this kind," to state that it must not be expected that it will supplant chemical analysis of oils in laboratories, but that it will serve as a rapid substitute for analysis in detecting the presence of mineral and resin oil adulterants in other oils where chemical analysis is not available. I said in my original presentation of the process that "I ventured to hope that it might even prove of assistance in chemical laboratories." Mr. Nemzek's first statement seems to more than confirm this anticipation.

Resistance of Ingrain Colors against Re-solution. W. P. DREAPER and A. WILSON. (*J. Soc. Dyers and Col.*, xxvii, 170)—In order to determine the influence of the temperature of dyeing of ingrain colors on the fastness of the shades obtained, samples of silk were dyed to the same shade with the pure sodium salt of the sulphonic acid of Primuline base at 100° C and 15° C. The dyed samples were then diazotized, developed with β-napthol, and subjected to the action of a 1 per cent. sodium oleate solution at 95° C. for one hour. The sample dyed at 15° C. lost 67 per cent. of color by re-solution, that dyed at 100° C lost only 17 per cent. When R salt was used as the developer, the loss of color after 10 minutes' soaping at 95° C. was 12 per cent. on the sample dyed at 100° C. and 94 per cent. on that dyed at 15° C. Samples dyed at 100° C. and 15° C. were developed with β-napthylamine, and after soaping lost 4 per cent. and 95 per cent. respectively. Similar, but less marked, results were obtained on dyeing cotton instead of silk.

Chromium Steels. PORTEVIN. (*Comptes Rendus*, cliii, 64.)—Guillet found that chrome steels with 0.1 per cent. of carbon and 7 to 22 per cent. of chromium were martensitic. Portevin shows that in this state they are not really stable, and that by extremely slow cooling from 1300°C. they can be brought into a state similar, in structure and hardness, to that of ordinary steels of the same carbon contents. If in this condition they are subjected to annealing in the ordinary, practical acceptation of the term, the effect is that of quenching; they become martensitic and increase considerably in hardness.

Wattmeter Errors at High Frequencies. E. BEHNE. (*Elektrotechnik u. Maschinenbau*, xxix, 257.)—The effect of the mutual induction between the fixed and movable coils of a wattmeter and the self-induction of the latter coils on the readings of the instrument was investigated. A number of calculations at 500 cycles per second were made, and it was shown that errors can be eliminated by putting a condenser in the moving-coil circuit. This was demonstrated by experiment.

Metallic Oxides as Arc Light Electrodes. B. MONASCH. (*Jour. Gasbel.*, liii, 1122.)—In endeavoring to discover some oxide, or mixture of oxides, for electrodes, that would be of greater efficiency than those now in use, it was found that the oxides of titanium, vanadium, yttrium, crium, uranium and tungsten were the most suitable; titanium oxide being the most efficient. Titanium oxide is more efficient than magnetite, and the more titanium oxide that is added to the magnetite, the more the efficiency of the electrode is increased, until the maximum is attained with pure titanium oxide.

FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting held Wednesday, November 15, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1911.

DR. GEORGE A. HOADLEY, *Temporary Chairman.*

Additions to membership since last report, 21.

The resolution from the Board of Managers recommending Professor Charles F. Chandler, Emeritus Professor of Chemistry, Columbia University, New York, N. Y., for honorary membership was adopted.

The paper of the evening was presented by Professor Cleveland Abbe, Ph.D., LL.D., of the U. S. Weather Bureau, Washington, D. C., on "Obstacles to the Progress of Meteorology."

Dr. Abbe spoke of the present impossibility of making long-range weather predictions on account of the limited data in the hands of the climatologist on the fundamental laws of radiation and of motion of gases.

He advocated the establishment of laboratories equipped for the experimental study of atmospherics for the benefit of meteorologists

At the close of the paper the thanks of the meeting were extended to Dr. Abbe.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, November 1, 1911, and the Adjourned Meeting, November 8, 1911.*)

DR. GEORGE A. HOADLEY *in the Chair at both Meetings.*

The following protests were considered:

No. 2489.—Hopkins Speedometer and Dynamometer. Sub-committee reappointed.

No. 2501.—Wolf's Liquid Gas. To be reconsidered by general committee.

The following report was presented for final action:

No. 2477.–Granbery's Stadia Rod. Advisory. Adopted.

The following report was presented for first reading:

No. 2499.—Santo Vacuum Cleaner. Reported progress.

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, October 26, 1911, at 8 o'clock.

The meeting was called to order by the president of the Section, Prof. A. E. Outerbridge, Jr. Sixty members and visitors were present. Professor Outerbridge presented his annual address as president of the Section on "A Practical Application of Fluorescence in Testing Oils for Industrial Purposes." (An abstract of the paper is printed in this issue.)

In connection with his remarks Professor Outerbridge gave a demonstration of his method of detecting mineral and resin oil impurities in vegetable oils, particularly in linseed oil used in making oil-sand cores. He also exhibited samples of such cores made with pure and with adulterated oil, as well as intricate castings illustrating the importance of the art of core-making.

After discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—By invitation of the Faculty of Pharmaceutic Chemistry of the Medico-Chirurgical College of Philadelphia, a meeting of the Section was held in the Chemical Lecture Hall of the College on Thursday, November 9, 1911, 8 P.M., with Prof. Carl Hering in the chair. Fifty-two members and visitors were present. The minutes of the previous meeting were read and approved. Prof. George H. Meeker, Ph.D., Dean of the Faculty of Pharmaceutic Chemistry of the Medico-Chirurgical College, presented a communication on "Some Electro-Chemical Experiments." The various experiments which show the migration of ions during the passage of an electric current through a solution, and which are described in the literature, were enumerated. Dr. Meeker then described a new experiment which demonstrates the migration of the ions, and also described and carried out certain experiments devised by himself which bear on the relation between the passage of the current and the migration of the ions. The paper was discussed by Doctors Goldsmith, Hillebrand, and Meeker, and by Professor Hering.

A vote of thanks was extended to Dr. Meeker, and the meeting adjourned to inspect the laboratories and apparatus of the college.

JOSEPH S. HEPBURN,
Secretary.

SURFACE COMBUSTION AND ITS INDUSTRIAL APPLICATIONS.

A communication on the above subject was presented to a large audience in the hall of the Institute on the evening of Monday, October 30, 1911, by Prof. W. A. Bone, D.Sc., Ph.D., F.R.S., Professor of Applied Chemistry, University of Leeds, England.

The speaker was introduced by President Walton Clark, and described his newly-discovered method for the production of high temperatures and its applications in the industries.

A large amount of apparatus was installed and numerous experiments shown illustrating the subject of his paper.

A full text will be printed in a future issue of the JOURNAL.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. JOHN J. BURLEIGH, Merchantville, N. J.
MR. WM. A. EVANS, 417 Mariner and Merchant Building, Philadelphia, Pa.
MR. L. H. FLANDERS, Electric Storage Battery Company, Philadelphia, Pa.
MR. BRUCE FORD, 25 East Summit St., Philadelphia, Pa.
MR. HENRY HESS, 2100 Fairmount Ave., Philadelphia, Pa.
MR. HERBERT LLOYD, Electric Storage Battery Company, Philadelphia, Pa.
MR. MALCOLM R. MACLEAN, American Steel Foundries, Chester, Pa.
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MR. EDWARD D. TOLAND, JR., 1211 Locust St., Philadelphia, Pa.
MR. JOSEPH H. TRACEY, Electric Storage Battery Company, Philadelphia, Pa.
MR. C. C. TUTWILER, 1706 North Broad St., Philadelphia, Pa.
MR. C. W. WOODWARD, Electric Storage Battery Company, Philadelphia, Pa.

NON-RESIDENT.

MR. C. W. ALLEN, 521 Oley St., Reading, Pa.
MR. CAXTON BROWN, Weston Electrical Instrument Company, Waverly Park, Newark, N. J.
DR. ARTHUR M. COMEY, Eastern Laboratory, Chester, Pa.
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MR. HUGH A. WILSON, Ashland, Pa.
MR. ROY V. WRIGHT, 192 Walnut St., East Orange, N. J.

ASSOCIATE.

MR. HOBART B. BAIRD, Y. M. C. A. Building, Wilmington, Del.
MR. HORACE C. KNERR, care Wirt Electric Specialty Company, Germantown, Philadelphia.

Changes of Address.

MR. R. M. ATWATER, Ladenburg, Thalman & Co., 25 Broad St., New York, N. Y.
MR. JAMES R. BIDDLE, 1211 Arch St., Philadelphia, Pa.
MR. DANIEL EPPELSHEIMER, 501 Broadway, Middletown, O.

Mr. A. W. Gibbs, Broad Street Station, Philadelphia, Pa.
Mr. A. O. Granger, Cartersville, Ga.
Mr. Frank Hepburn, General Delivery, Jacksonville, Fla.
Mr. Jonathan R. Jones, Morris Building, Philadelphia, Pa.
Mr. H. I. Kaltenthaler, 202 East Washington Lane, Germantown.
Mr. C. O. Mailloux, 519 West End Ave., New York.
Mr. James McGowan, Jr., 3420 Race St., Philadelphia, Pa.
Mr. J. N. Pew, Morris Building, Philadelphia, Pa.
Mr. S. D. Smith, 1616 Redfield St., Philadelphia, Pa.
Mr. Ralph C. Stewart, 514 Commonwealth Trust Building, Philadelphia, Pa.
Mr. A. P. Stout, 404 Market St., Bethlehem, Pa.
Mr. Louis Taws, 609 Lincoln Drive, Germantown, Philadelphia, Pa.
Mr. G. C. Vogel, 409 Terrace Ave., Milwaukee, Wis.
Mr. O. L. West, Bourse Building, Philadelphia, Pa.
Mr. B. C. Wolverton, 207 State St., Syracuse, N. Y.

NECROLOGY.

Rev. Henry Christopher McCook, D.D., Sc.D., LL.D., Presbyterian clergyman, author and entomologist, honorary member of the Institute, died at his home in Devon on October 31st.

Dr. McCook was born in New Lisbon, O., July 3, 1837. In early boyhood he was a printer's apprentice. Later, changing his views, he determined to study the law, but finally decided to enter the ministry. He graduated from Jefferson College, at Canonsburg, now Washington and Jefferson College at Washington, in 1859, and took up his further course at the Western Theological Seminary, Allegheny.

Dr. McCook was known throughout the country not only for his prominence as a clergyman, but perhaps even more widely for his achievements in the science of entomology. His works on ants and spiders are especially valuable, and he was recognized as an authority on these insects.

Dr. McCook's first active work in the ministry was as chaplain of the 41st Illinois Volunteers in 1861–62. He always maintained his interest in military organizations, and was Chaplain of the Pennsylvania Commandery of the Loyal Legion and of the Second Regiment. He was also the founder of the National Relief Commission in the Spanish-American War. He was president of the American Entomological Society, vice-president of the Academy of Natural Sciences and president of the American Presbyterian Historical Society.

Dr. McCook's work in church heraldry has placed his name foremost in this line. He designed the seal of the Presbyterian Church in this country, adopted in 1892 by the General Assembly. He was an honorary member of the British Association for the Advancement of Science, and was one of the managers of the Wistar Institute and a trustee of the Presbyterian Hospital.

Dr. McCook's publications have been voluminous. They include "Agricultural Ants of Texas," "Honey and Occident Ants," "American Spiders and their Spinning Work" (a work in three volumes), "Tenants of an Old Farm," and "Old Farm Fairies." All of these are scientific works. Other works by Dr. McCook are: "Ecclesiastical Emblems," "The Latimers" (A Scotch-Irish historical romance), "Martial Graves of our Fallen Heroes in Santiago de Cuba—A record of the Spanish-American War," and "The Senator—A Threnody in Verse and Prose."

Miss Mary R. Burton
Mr. Henry J. Crump
Mr. Jarvis B. Edson
Mr. Howard Wood

LIBRARY NOTES.

Purchases.

International Catalogue of Scientific Literature. B. Mechanics. Ninth annual issue.
International Catalogue of Scientific Literature. E. Astronomy. Ninth annual issue.
International Catalogue of Scientific Literature. J. Geography. Ninth annual issue.
SEIDELL, A.—Solubilities of Inorganic and Organic Substances.
MEYER, R.—Jahrbuch der Chemie.
DUNCAN, J. C.—Principles of Industrial Management.
BROOKS, J. P.—Reinforced Concrete.
ABBOT, C. G.—The Sun.
REDMAYNE, R. A. S.—Modern Practice in Mining. 3 volumes.
BARTHOLOMEW, J. G.—Cassell's Atlas.
DUNCAN, R. K.—Some Chemical Problems of To-day.
CARDULLO, F. E.—Practical Thermodynamics.
MOYER, J. A.—Power-plant Testing.
United States Patent Office.—Manual of Classification of the German Patent Office.
RUDZKI, M. P.—Physik der Erde.
STARKE, H.—Experimentelle Elektrizitätslehre.
HOWE, G.—Mathematics for the Practical Man.
GANTT, H. L.—Work, Wages, and Profits.
BORCHERS, W.—Electric Furnaces.
BAEDEKER, K.—Die elektrischen Erscheinungen in metallischen Leitern.
TAYLOR, F. W.—The Principles of Scientific Management.
KERSHAW, JOHN B. C.—The Electric Furnace in Iron and Steel Production.
Annual Library Index. 1910.
Iron and Steel Institute Journal. Index vols. 59-82.
NAGEL, O.—The Lay-out, Design, and Construction of Chemical and Metallurgical Plants.

WOOD, R. W.—Physical Optics. Second edition.
FLEMING, J. A.—The Propagation of Electric Currents.
EVANS, J. C.—Physico-chemical Tables. 2 volumes.

Gifts.

New South Wales. Annual Report of the Department of Mines for the year 1910. Sydney, 1911. (From the Department.)
Amsterdam Academy of Science. Proceedings of the Section of Sciences. Vol. 13, parts 1 and 2. Amsterdam, 1910-1911. (From the Academy.)
Amsterdam Academy of Science, Year-Book 1910. Amsterdam, 1911. (From the Academy.)
Vermont Insurance Commissioners. Report for year ending December, 1910. Concord, 1911. (From the State Library.)
New York State Museum. Report for 1909. Vols. 1-5. Albany, 1911. (From the State Library.)
San Fernando. Instituto y Observatorio de Marina. Almanaque Nautico, 1913. San Fernando, 1911. (From the Observatory.)
Canada Year-Book 1910. Ottawa, 1911. (From the Census and Statistics Office.)
Antikvarisk Tidskrift for Sverige, No. 19, Utgifven af Kungl. Vitterhets Historie och Antikvitets Akademien. Stockholm, 1911. (From the Academy.)
Hamilton Association, Journal and Proceedings. Nos. 25 and 26. Sessions 1908-09 and 1909-10. Hamilton, 1910. (From the Association.)
Illinois Bureau of Labor Statistics. Bulletin. Labor legislation enacted by the 47th General Assembly, 1911. Springfied, 1911. (From the Bureau.)
Pennsylvania Topographic and Geologic Survey Commission Report, 1908-1910. Harrisburg, 1911. (From Mr. E. V. d'Invilliers.)
New South Wales Official Year-Book, 1909-10. Sydney, 1911. (From the Bureau of Statistics.)
Philadelphia Bureau of Water, 109th annual report, for the year 1910. Philadelphia, 1911. (From the Bureau.)
Alabama Geological Survey. Bulletin No. 10. Reconnoissance Report on the Fayette Gas Field. Bulletin No. 11, Roads and Road Materials of Alabama. Montgomery, 1911. (From the Survey.)
Ohio State Mining Department, 36th annual report of the Chief Inspector, for 1910. Columbus, 1911. (From the Department.)

BOOK NOTICES.

CARNEGIE INSTITUTION OF WASHINGTON PUBLICATIONS:

No. 119. PERRINE, CHARLES D. Determination of the Solar Parallax from Photographs of Eros made with the Crossley Reflector of the Lick Observatory. Quarto, v+98 pages, 1 plate, 2 text figures. Published 1911. Price, $2.50.

This publication gives a detailed account of observations and computations made in deriving the solar parallax from photographs of the minor planet Eros taken by means of the Crossley reflecting telescope of the Lick Observatory during the interval October, 1900, to January, 1901. The value of the parallax deduced is 8.8067′ ± 0025″.

No. 138. ADAMS, WALTER S., assisted by JENNIE B. LASBY. An Investigation of the Rotation Period of the Sun by Spectroscopic Methods. Quarto, III+132 pages, 2 plates, 5 text figures. Published 1911. Price, $3.

The results of a determination of the rotation period of the sun from the displacements of the spectrum lines. The material employed consists of two series of photographs obtained at the Mount Wilson Solar Observatory during the years 1906-7 and 1908 with fixed spectrographs of high dispersive power. The methods of observation and reduction are discussed in full, and a comparison is made with the results of other observers and with the values of the rotation period as derived from studies of sun-spots, faculæ and flocculi.

Special series of observations with lines of hydrogen and calcium indicate a more rapid period of rotation for the gases of these elements as well as a modification of the law of the equatorial acceleration. Similar results to a less degree are found for certain of the weaker lines of the reversing layer.

No. 147. RUSSELL, HENRY NORRIS. Determinations of Stellar Parallax, based upon Photographs taken at the Cambridge Observatory by Arthur R. Hinks and the writer; with Magnitudes and Spectra determined at the Harvard College Observatory under the direction of Prof. E. C. Pickering. Quarto, VI+142 pages. Published 1911. Price, $2.

This work is based on 254 plates and 37 different fields, taken with the Sheepshanks *equatoréal coudé* of 12 inches aperture and 20 feet focal length. The relative parallaxes of 52 stars especially selected for observation, and of 242 others chosen as objects of comparison, have been determined. Every precaution was taken to eliminate systematic error; and the discussion of the results for the comparison-stars indicates that the residual errors—whether depending on a star's position, magnitude, or spectral type, or on the season of the year at which observations were made—cannot exceed a few thousandths of a second of arc. As regards accidental errors, the results appear also to be of high precision. The conditions suitable for obtaining the most accurate results for a given amount of work expended are next discussed, and later the astrophysical conclusions derivable from the data for the principal stars. Detailed tables of the numerical results of observation conclude the volume.

No. 149. BARUS, CARL. The Production of Elliptic Interferences in Relation to Interferometry. Octavo, VI+77 pages, 33 text figures. Published 1911. Price, $1.25.

In the cases of coronas there is a marked interference phenomenon superposed on the diffractions. This suggested the present investigation, which aims at a simplification of the effect in question by bringing two complete component diffraction spectra, from the same source of light, to interfere. Many ways are shown to be available, the methods being either direct (as discussed in Chapters II and III, where a plane mirror immediately behind the grating returns reflected-diffracted and diffracted-reflected rays) or indirect, using the devices of Jamin, Michelson, and others (Chapters IV and V). In Chapter I a modification of Rowland's apparatus, suitable for plate gratings, is described. The direct method gives equidistant fringes, duplex in character, but rigorously straight throughout the spectrum, their distances apart and inclinations being measurable by ocular micrometry. Lengths and small angles are thus subject to micrometric measurement. In case of the indirect method, the half-silvered plate is replaced by the grating; the fringes are, as a rule, approximately elliptic (confocal) throughout the spectrum, and the fringes again partake of both a drift and radial motion, when the interferometer adjustment is altered. Drift and radial motion may be regulated in any ratio. The theory of the subject is worked out, in so far as it bears on the practical results obtained.

A SYSTEMATIC HANDBOOK OF VOLUMETRIC ANALYSIS. By Francis Sutton. Tenth edition by W. L. Sutton and A. E. Johnson. Philadelphia: P. Blakiston's Son & Co.

"Sutton" is the standard work on Volumetric Analysis, and while other excellent works on this subject have been published in the English language during the period of forty years since the appearance of the first edition, the present thoroughly-revised and much improved edition may fairly claim a place upon the book-shelves of every analyst as the most comprehensive and up-to-date treatise on the subject.

In comparing this tenth edition with the preceding ones, we cannot help being very favorably impressed with many new features and conspicuous improvements of the text. Thus the sections on the instruments of precision employed in volumetric analysis have been entirely rewritten with the assistance of R. J. Glazebrook, of the National Physical Laboratory. The term "normal solution" is more exactly defined, and the section on Indicators materially amplified. Many obsolete processes have been eliminated, and a considerable number of new methods introduced. Among the latter we note especially those under "Ammoniacal Liquors," "Ferrocyanides," "Acetone," "Oils, Fats, and Waxes," and many of the metals. A decided improvement, too, has been effected in carrying all the references in the text to the foot of the page.

In spite of the many changes, the size of the book has been only very slightly increased, and the editors deserve much praise for having accomplished this without altering the scope and character of this standard work.

H. F. KELLER.

WOLFRAM: eine Monographie. By Heinrich Leiser, Ph.D. Pp. 222. Halle a. S.: Wilhelm Knapp. Price, paper, 12 marks.

Although tungsten was discovered 130 years ago, it is only two decades since this metal has found extended industrial applications. In view of these, and particularly the uses of tungsten in the manufacture of incandescent electric lamps and of special steels, the publication of a monograph, such as this, must be hailed as a most welcome addition to the literature of industrial chemistry.

Following a brief historical sketch of the element, the book contains a very complete account of our present knowledge of it, under the headings: 1. Occurrence of the tungsten ores; 2. The manufacture of the tungsten salts and the metal; 3. The chemistry of tungsten and analysis of the tungsten products; 4. The physical and physiological properties of tungsten; 5. Industrial applications: the tungsten lamp and the high-speed steels; 6. The alloys of tungsten; 7. Other uses of tungsten and tungsten products; and an appendix on the patent claims relating to the tungsten lamp.

While we miss in this book a number of contributions made to the chemistry and applications of tungsten by American investigators and inventors, it presents the subject in a well-arranged and usable form, and contains a wealth of valuable information not readily to be found elsewhere. It is printed in clear type on good paper.

H. F. KELLER.

TRAITÉ DE RADIOACTIVITÉ. Par Madame P. Curie. In 2 volumes. Paris: Gauthier-Villars, 1910.

It would be difficult to instance in the history of science a parallel to the rise and development on that new and flourishing branch of physical science which is called radioactivity. Only fifteen years have elapsed since the late Henri Becquerel made the great and fundamental discovery of the peculiar radiations emitted by uranium, and to-day our knowledge of such radiations and their sources, acquired by means of physical and chemical methods in the hands of some of the most distinguished investigators of our time, constitutes an independent science whose extended border-line is drawn with peculiar sharpness.

Among those who have actively contributed to these vast new stores of knowledge no one stands out more conspicuously, in respect to both the extent and importance of his or her discoveries, than the author of this latest and most authoritative treatise on the subject. Shortly after Becquerel's fundamental discovery Mme. Curie succeeded in tracing the uranium rays to their source, demonstrating that they are an atomic property of uranium, and in isolating from uranium ore new and vastly more radioactive substances—polonium and radium. In part of these investigations, as well as in many that followed, she enjoyed the coöperation of her husband, Prof. Pierre Curie, whose lamented death occurred in 1906. Since that time she has uninterruptedly continued her beautiful researches in the field in which she and her husband will ever be recognized as the pioneers.

Mme. Curie was also the first writer who gave a connected and satisfactory account of the early work done in radioactivity. She published it as a thesis for the Doctorate in 1903, under the title, "*Les Substances Radioactives.*" Since then a great number of books on the subject have been written in many languages, the best one, undoubtedly, by Prof. Ernest Rutherford. This excellent work, which has passed through several editions and has been translated into other languages, served as the chief work of reference on radioactivity for the past five years. The phenomenal strides, however, by which the new science has been advancing in recent years have created a demand for a still larger and more complete treatise on the subject, and the present work was written to meet this want.

As Mme. Curie tells us in the preface, the book is founded upon a course of lectures she delivered at the Sorbonne as professor of the *Faculté des Sciences*. It is, therefore, addressed to the special student of the subject rather than to the general reader.

It will suffice here to indicate in a general way the contents of the several chapters, and to add a few remarks on the character of this new standard work.

Volume I begins with a discussion of Ions and Electrons, which is followed by chapters under the following captions: Methods of detecting and measuring radioactivity; radioactivity of uranium and thorium, radioactive minerals; the new radioactive substances; transient radioactivity; radioactive gases, or emanations; induced radioactivity; the theory of radioactive transformations.

Volume II is devoted to an exhaustive discussion of the nature of the radiations; the phenomena occurring in the presence of the radioactive substances; the description of the several "families" of radioactive elements; the genesis and relations of these elements; and it concludes with a chapter on the radioactivity of the sun and of the atmosphere.

The presentation of the subject is inductive rather than historical. The development is admirably logical and reveals the author's masterly command both of the methods and the literature of all that pertains to radioactivity. Full recognition is accorded to the labors of other investigators, and no undue prominence is given to the researches of the author and her associates. A careful examination of the text discloses the painstaking care with which it was prepared for the press, and that it is remarkably free from typographical errors. The typography, indeed, is most excellent, as is also the paper. The illustrations are clear and appropriate. A fine portrait of Pierre Curie adorns this work as the frontispiece: a tender and fitting tribute to his memory.

H. F. Keller.

PUBLICATIONS RECEIVED.

A Short Course in the Testing of Electrical Machinery for Nonelectrical Students. By J. H. Morecroft and F. W. Hehre. 154 pages, illustrated, 8vo. New York, Van Nostrand Co., 1911. Price, cloth, $1.50 net.

Allen's Commercial Organic Analysis: A Treatise on the Properties, Modes of Assaying, and Proximate Analytical Examination of the Various Organic Chemicals and Products. . . . Volume 5. Tannins, analysis of leather, dyes and colouring matters, dyestuffs of groups 6 to 12, colouring matters of natural origin, analysis of colouring matters, colouring matters in foods, inks. . . . Fourth edition, entirely rewritten. 704 pages, 8vo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, cloth, $5 net.

U. S. Bureau of Mines. Miners' Circular 5. Electrical Accidents in Mines: Their Causes and Prevention. By H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 10 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

U. S. Coast and Geodetic Survey. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Baldwin, Kans., 1907–1909, by Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 114 pages, plates, 4to. Washington, Government Printing Office, 1911.

U. S. Bureau of Mines. Bulletin No. 13, Résumé of Producer-gas Investigations, October 1, 1904, to June 30, 1910. By R. H. Fernald and C. D. Smith. 393 pages, illustrations, plates, tables, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Agriculture, Office of Public Roads. Circular No. 96, Naphthaline in Road Tars. 1. The Effect of Naphthalene upon the Consistency of Refined Tars. By Prevost Hubbard, chemist, and Clifton N. Draper, assistant chemist. 12 pages, 8vo. Washington, Government Printing Office, 1911.

Pennsylvania Topographic and Geologic Survey, Report 1908–1910. 103 pages, illustrations, plates, maps, 8vo. Harrisburg, State Printer, 1911.

U. S. Department of Agriculture, Forest Service. Circular No. 187. Manufacture and Utilization of Hickory, 1911. By Charles F. Hatch, Statistician in Forest Products. 16 pages, 8vo. Washington, Government, 1911.

Di-el-lite Resistance Units (Resistors). Descriptive pamphlet. 12 pages, illustrations, 8vo. Philadelphia, Wirt Electric Specialty Co., 1911.

Rensselaer Polytechnic Institute. Engineering and Science Series No. 1, Metallic Titanium. By Matthew A. Hunter. 12 pages, illustrations, 8vo. Troy, N. Y., Institute, 1911.

U. S. Bureau of Mines. Bulletin 19, Physical and Chemical Properties of the Petroleums of the San Joaquin Valley of California. By Irving C. Allen and W. A. Jacobs. With a chapter on natural gas from the oil fields of Southern California by G. A. Burrell. 60 pages, plates, 8vo. Washington, Government, 1911.

U. S. Coast and Geodetic Survey. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Vieques, Porto Rico, 1907 and 1908, by Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 98 pages, plates, 4to. Washington, Government, 1911.

Royal Institution of Great Britain. Weekly evening meeting. March 10, 1911—Recent Advances in Turbines, the Hon. Sir Charles A. Parsons. March 31, 1911—Travelling at High Speeds on the Surface of the Earth and Above it, Prof. H. S. Hele-Shaw. May 5, 1911—New Organic Compounds of Nitrogen, Prof. Martin O. Forster. May 12, 1911—Biology and the Cinematograph, Prof. William Sterling. June 2, 1911—Radiotelegraphy, Commendatore, G. Marconi. 5 pamphlets, illustrations, plates, 8vo. London, Institution, n. d.

CURRENT TOPICS.

"New Data on Some Electrical Properties of Sodium, Potassium, and Their Alloy."—Under the above title Dr. Edwin F. Northrup, of the Palmer Physical Laboratory, Princeton University, presented to the American Electrochemical Society the results of an investigation, of which the following is an abstract:

A glass tube with platinum potential and current terminals was first filled with pure mercury and the resistance of this was determined between the potential points in the temperature range 21.48° to 106.8° C. The same tube was then filled with molten sodium and the resistance of this determined in the range of temperature 21.4° to 141.2° C. The same was done for potassium in the range 21.2° to 63.2° C., and for an alloy of equal parts by volume of sodium and potassium in the range 2.8° C. to 131.2° C.

Using the known constants for mercury, the temperature coefficients and the specific resistances of the sodium, potassium, and the alloy were deduced from the observed data. A summary of the results deduced is given in the table below. Other facts of interest brought out are the following:

Substance	Spec. Res. at 20° C. $10^{-9} \times$	Spec. Res. at 100° $10^{-9} \times$	Temp. Coef. Low Range	Temp. Coef. High Range	Density at 6°
Mercury	95782	103560	0.001003 (20° to 100°)	. . . .	13.595
Sodium	4873	9724	0.0053 + (20° to 80°)	0.00494 + (100° to 140°)	0.978
Potassium . . .	7116	15306	0.0058 (20° to 50°)	0.00507 + (66° to 120°)	0.87
Alloy, K+Na .	33792	37872	. . . .	0.00147 (46° to 125°)	0.92
Copper	1721	2266	0.00387 +	. . . .	8.89

Sodium in passing from the solid state at 93.5° C. to the liquid state at 96.3° C. experiences an abrupt increase in resistance of 44.8 per cent.; potassium in passing from the solid state at 60.4° C. to the liquid state at 63.2° C. increased 52.2 per cent.; and the alloy, equal parts by volume in passing from 2.8° C., at which temperature it is completely solid, to 20° C., at which temperature it is completely liquid, increased 48.5 per cent. The temperature coefficient of potassium in the range of 20° to 50° is 0.0058, and of sodium in the range of 20° to 80° is 0.0053. The coefficient of the alloy of potassium and sodium, instead of being the mean of the coefficients of sodium and potassium when liquid, is only between a third and a fourth of the mean value of the coefficients of its constituents in the same temperature range.

The mean specific resistance at 100° C. of sodium and potassium is but about one-third the mean specific resistance of the alloy of these two metals in equal proportions by volume at the same temperature.

The ratio of the resistivity at 20° C. of sodium to copper is 3.058, but the density of copper is almost exactly nine times that of sodium, which in round numbers makes sodium three times as good a conductor per unit of weight as copper. Hence it could compete with copper as a conveyor of electric power if it cost anything less than three times as much as copper per pound, provided current carrying capacity were the only consideration. Sodium has been quoted at $0.25 a pound. If confined in iron pipes it might be an economical conveyor of electric energy over short distances for the enormous currents used in electrochemical processes.

Sulphur Production an American Industry. (*United States Geological Survey Report.*)—The United States produced 255,534 long tons of sulphur in 1910, valued at $4,605,112, according to figures compiled by W. C. Phalen, of the United States Geological Survey, and just published as an advance chapter from "Mineral Resources." This is an increase of 16,222 tons in quantity and $173,046 in value over the output for 1909.

The sulphur industry in this country is substantially an American one, for the imports for 1910 were valued at only $558,611, while the exports amounted to $552,941. Four States—Louisiana, Nevada, Utah, and Wyoming—produced practically all of our sulphur. Mr. Phalen discussed the geological occurrence and technology of sulphur in the 1909 chapter of "Mineral Resources." In the chapter for 1910 he gives a detailed account of the important foreign sulphur deposits—those of Italy, Japan, and other countries.

The report also contains the statistics of production of pyrite in the United States, which in 1910 amounted to 238,154 long tons, valued at $958,608. The imports of this mineral were largely in excess of the domestic production, being 803,551 long tons in 1910, valued at $2,748,647. A copy of the report can be had on application to the Director of the United States Geological Survey, Washington, D. C.

The Genealogy of Some Radio-active Bodies. ANON. (*Cosmos*, No. 1369, 423.)—The radio-active chemical elements are transmuted from one to another either by evolution or by descent. Although it is customary to specially distinguish only a small number of these elements, such as uranium, thorium, and radium, it must not be overlooked that a great variety of intermediary radioactive elements exist, which owe their existence to those which have a more or less long life. For instance, let us consider the genealogical tree of *thorium*. This radio-active metal first disintegrates, transforming itself into *meso-thorium I*, which has a middle life of 8 years (that is to say, a given mass of meso-thorium I is reduced to one-half at the end of 8 years) and then changes into *meso-thorium* II, which in its turn wears out in 9 hours, with the emission of β rays (negative electrons) and γ rays (analogous to X rays), becoming radio-thorium. Each atom of radio-thorium expels an α particle (a positive particle of electricity, which is known to be identical with an atom of electrified helium) and becomes *thorium X*, which disintegrates into the *thorium emanation*, a gas the middle life of which is only 77 seconds, and which by the loss of an α particle changes into *thorium A*, which is succeeded by *thorium B*, *thorium C*, and *thorium D*; the final product is still unknown. As large quantities of thorium are treated in the manufacture of incandescent gas mantles, considerable quantities of meso-thorium and radio-thorium have been extracted; the elements mentioned in the preceding list. These radio-active preparations are used chiefly medicinally.

Professor Soddy has found that meso-thorium and radium have the same chemical properties. Moreover, according to his researches, thorium, ionium and radio-thorium form a first group of radio-active elements; another group includes meso-thorium, radium and thorium X. The chemical properties of the members of each group are the same, although the atomic weight of each element differs from that of the next by two units. On the other hand, meso-thorium, which is at the head of the second group, and radio-thorium, the last of the first group, have different chemical properties, although they have the same atomic weight. From these curious considerations, which chiefly concern the lineage of radio-active thorium, the ideas of Sir W. Ramsay as to radium may be approached. *Radium*, with an atomic weight of 226.5, disintegrates into an ephemeral radio-active gas, the *radium emanation*, which Ramsay has proposed to name *niton* (atomic weight 222.5); in its turn, passing through a series of phases, some long and others very short, this emanation transforms itself into *helium* (atomic weight 4). On comparing the atomic weight of these three elements, it is seen that the atomic weight of radium is equal to the sum of the atomic weights of the two others. This has led Ramsay to consider that radium is formed by the culmination of niton and helium. This would be helium nitonide, which constantly undergoes partial destruction, disengaging considerable energy.

Hot Bearing Avoided by the Use of Sheet Lead. ANON. (*Amer. Mach.*, xxxv, 167.)—One of the journals of a heavy locomotive gave continual trouble by running hot. The assumption was that this was caused by an overhard brass bearing in the box. The box was raised about ¼ inch off the journal, and a piece of thin sheet lead was inserted between the shaft and the bearing surface of the brass bearing. The lead was thus worked into the pores of the brass, and the heating of the bearing ceased.

Distillation of Tin in Vacuo. E. TIEDE and F. FISCHER. (*Ber.*, xliv, 1711.)—Although tin melts at 230° C. it has a very high boiling point and is difficult to distil. This can be effected by heating several grammes electrically in a small magnesia or porcelain tube. The heating coil of platinum wire is wrapped around the tube and the whole system placed in an exhausted glass vessel, the outer walls of which are well cooled by flowing water. The first product of distillation is a yellow deposit, which gradually darkens and becomes almost black. The yellow powder, which is found with all varieties of tin, appears to possess all the properties of stannous sulphide. If the tin be prepared under special conditions so as to be quite free from sulphur, only a black distillate of pure tin is obtained, but in the air of the laboratory, this soon becomes contaminated with sulphide.

Behavior of Solid and Liquid Copper towards Gases. A. SIEVERTS and W. KRUMBHAAR. (*Zeit. Phys. Chem.*, lxxiv, 3, 277.) —In investigating this question the following conclusions were reached: (1) Oxygen is dissolved by molten copper in the cuprous state, and is not given off on solidification even in an oxygen-free atmosphere. (2) Nitrogen, carbon monoxide and carbon dioxide are not absorbed either by solid or liquid copper. (3) Solid copper absorbs hydrogen. (4) Solid copper does not absorb sulphur dioxide, but the molten metal absorbs a considerable quantity.

Sofia International Exhibition, 1912.—An exhibition of Industry, Commerce, Agriculture, Art, Education, Hygiene, Food, and Sports will be held at Sofia, Bulgaria, during the summer of 1912.

It will open early in June and continue until August or September. The movement is under the patronage of the Government of Sofia, and has the coöperation of the Chamber of Commerce and Industry.

The Royal Minister of Commerce and Agriculture of Bulgaria is honorary president of the Exhibition Association.

Further details can be had by addressing the Organization Committee of the International Exhibition, 1912, Sofia, Bulgaria.

Influence of Copper on the Acid Corrosion Test. W. H. WALKER. (*Met. and Chem. Eng.*, ix, 453.)—The rate at which iron or steel is attacked by acid is no criterion of its purity, since the commercial metal frequently contains small quantities of copper which Breuil has shown (*J. Iron and Steel Inst.*, 1907) greatly reduces its tendency to dissolve. On examining a number of specially-prepared samples, to some of which about 0.2 per cent. of copper was added during manufacture, the test pieces were exposed to the action of 20 per cent. sulphuric acid for three hours. The loss on each of the specimens free from copper was about 0.22 gramme, that on those containing copper varied from 0.0095 to 0.0075 gramme.

Blast Furnace Smelting with Oil. E. JACOBS. (*Eng. and Min. Jour.*, xcii, 434.)—Quoting from T. Kiddie's report, the author gives the results of a trial smelting of copper ore in a blast furnace using oil as fuel. The ore was obtained from the Boundary District of British Columbia, and the flux was composed of iron ore mixed with the slag from a previous operation. The rate of smelting was 110 tons per 24 hours, and the average consumption of oil was 14.6 gallons per ton of material smelted. The cost for oil was 43.8 cents per ton of ore.

British Regulations for the Sale of Acids. ANON. (*London Gazette*, Sept. 29, 1911.)—The new regulations for the retail sale of mineral acids are now in force. Sulphuric acid, nitric acid, and hydrochloric acid must only be sold retail in bottles distinguishable by touch from ordinary bottles and labelled with the name and address of the seller and with the words, "Poisonous" and "Not to be taken." These regulations have been made by the Privy Council in order to prevent accidents through the misuse of these acids. During 1909, 99 deaths were caused by hydrochloric acid, 7 by nitric, and 7 by sulphuric acid. Besides these fatalities, numerous accidents are frequently occurring, due to acids being contained in an ordinary bottle improperly labelled. Any person selling these acids without observing the new requirements will be liable to a fine of £5 ($25). In four months' time ammonia will be subject to the same regulations.

(It would be well for the United States to take the hint.)

Aluminum Nitride, Alumina, and Nitric Acid. G. L. BOURGEREL. (*Monit Scient.*, 1911, 561.)—By heating a mixture of bauxite and carbon in an electric furnace in a stream of nitrogen, an aluminum nitride, containing about 24 per cent. of nitrogen, is obtained, which on treatment with sodium hydroxide solution yields ammonia and sodium aluminate. The ammonia can be oxidized to nitric acid, and from the sodium aluminate, aluminum oxide can be obtained for the production of aluminum. However, if this process were used as a source of nitric acid or nitrates, there would be an enormous and unremunerative overproduction of aluminum. If the aluminum compounds simultaneously produced are disregarded, the cost of production of nitric acid or nitrates would be greater than the present price of sodium nitrate, or than the price at which it can be produced by direct electro-thermic synthesis. By the direct process 166 kilos of nitrogen can be fixed, or 744 kilos of nitric acid produced, per kilowatt-year, and at an estimated cost of 70 fr. ($14) per horse-power-year in France. There is a prospect of the industry developing so as to compete with the nitride process, and supply the whole need of the country.

De-oxidation of Steel by Molten Ferromanganese. J. BRONN and W. SCHEMMANN. (*Stahl und Eisen,* xxxi, 1375.)—The use of molten ferromanganese results in a considerable saving of manganese, but this advantage is neutralized by the loss of manganese by volatilization when ferromanganese is melted in cupola, reverberatory, or ordinary arc electric furnaces. With a special furnace constructed to permit the use of arcs of low potential difference between the electrode and metal bath, ferromanganese can be heated considerably above its melting point without loss of manganese. Satisfactory results have been obtained with a small Röchling-Rodenhauser induction furnace. The molten ferromanganese is added to the steel as it is poured from the converter into the casting ladle, and is distributed so uniformly that there is no difference in manganese content between the first and last castings from a charge of 23 tons. Only about 35 per cent. of the usual amount of manganese is required.

Gases Contained in Steels. G. CHARPY and S. BONNEROT. (*Compt. Rend.,* clii, 1247.)—In the course of researches on cementation, a series of experiments were made on the gases liberated when steels are heated to 950° C. in vacuo. Under these conditions the velocity of liberation diminishes rapidly during the first few hours, but afterwards reaches a limit, indicating that part of the gas is liberated by a progressive reaction, and that it is not all dissolved or occluded. The initial velocity of evolution is greater with small chips and decreases with increase of pressure, but the ultimate total volumes liberated from equal weights of steel are the same. The volume of gas evolved from 1 gramme of steel varies from 0.31 to 1.06, according to the kind of steel. Although the gases contained 26 to 32 per cent. carbon monoxide, the quantity evolved appears to be quite independent of the carbon content of the steel.

A New Form of Metallic Filament Lamp. BOURRELLY. (*Soc. Belge Elect. Bull.,* xxviii, 165.)—After a summary of the chief qualities of tantalum and tungsten lamps, it is pointed out that the shape of the filament in the latter causes most of the light to be emitted sideways and very little downwards. Some new forms of the "Leila" type of lamp are described, with new methods of mounting the filament. In one the filament is arranged horizontally, in another there is a combination of vertical and horizontal filaments, and in a third a group of filaments converging downwards to a point is utilized, and the distribution of light is improved.

Soda Beds in British East Africa. ANON. (*Revue Sci.*, xlix, 11, 345.)—The great soda beds of the famous "Soda Lake" at Magadi, in East Africa, estimated to contain 200,000,000 tons, will shortly be worked by an English company with a capital of $5,000,000. The Government has agreed to continue the railroad from Uganda to the lake. The lake has an area of about 20 square miles. During the very short rainy season it is covered by a few inches of water, which will not materially interfere with the work. These beds consist of several well-defined, horizontal layers; the upper one is about 10 inches deep. As soon as a block of soda is extracted another crust forms in its place, and the natives claim this reproduction is effected so quickly that they can obtain soda from a given point for quite a number of years. There is reason to believe that these beds extend to the full depth of the valley in which the lake lies. One bore-hole, 9 feet deep, passed through a solid mass of crystallized soda. An average depth of 9 feet over the whole bed is the basis for the estimate of 200,000,000 tons.

Scientific Fisheries Service in France. ANON. (*Revue Sci.*, xlix, 11, 346.)—Five naturalists are engaged on this service. The deputy, M. F. Coreil, has proposed a law to make this official and to organize a scientific fisheries service under the Ministry of Marine. This proposition has been referred to the Commission of Marine Affairs.

The Action of Air Upon Coal. M. LÉCRIVAIN. (*Elect. Rev.*, lxviii, 910.)—All coals suffer characteristic oxidation in air, the ultimate result being spontaneous combustion if this oxidation continues for a sufficient time. The process of slow change which occurs at first can be divided into the following well-marked stages: (*a*) The physical state of the coal is altered. Surface oxidation causes minute fissures, which rapidly extend right through the lumps; thus the size of the sound pieces continually decreases. (*b*) A change of weight occurs in three stages: (1) loss by escape of moisture and occluded methane; (2) gain by surface oxidation; (3) loss by escape of hydrocarbons formed by the partial decomposition of the coal. Stages 1 and 2 occupy more or less time, according to the exact state and nature of the coal, but spontaneous combustion rapidly follows on stage 3. (*c*) A loss of calorific power and a deterioration of lighting and cooking values follow the escape of gases from the coal. If the carbon content of the coal be low, and the atmospheric temperature high, this loss of gas is very rapid and may easily exceed 30 per cent. in one month's exposure. (*d*) The available by-products are diminished and the quality of the coke deteriorates. The quantity of ammonium salts recoverable may decrease 50 per cent. during three or four months. Coal stacked in the open air is bound to deteriorate, but the fire risk may be decreased by building only low banks. Storage under water is the best and safest procedure.

The Manufacture of Small Incandescent Lamps. ANON. (*Electrical World,* lvii, 1240.)—There are unusual difficulties in making lamps for switchboard service, as the carbon filament used has a diameter of 0.002 inch, about equal to that of a human hair. The Western Electric Company has made special lamps of this kind for telephone switchboard use. Intermittent lighting up and extinguishing does not affect them prejudicially, and some have been in use for over 50,000 hours' service and have undergone over a million flashes. The standard lamp for this work consumes 0.1 ampère at 24 volts; the bulbs are 1¾ inches long and 5/16 inch diameter. The resistance is about 250 ohms. Metallic filaments are unsuitable on account of their low resistance. The method of squirting and mounting such filaments is described in detail. Mercury pumps, though generally discarded for exhausting large-bulb lamps, are still used sometimes for miniature lamps.

Chromatic Aberration and Visual Acuity. L. BELL. (*Electrical World,* lvii, 1163.)—The eye cannot readily focus light of various wave lengths simultaneously; hence it is suggested that the most perfect definition will be secured by using monochromatic light; for this purpose the mercury vapor lamp and flame arcs, which are approximately monochromatic, are good. Experiments with an acuity photometer support the view that monochromatic light possesses a power of revealing detail greater than its photometrically measured brightness would indicate.

A New Indicator for Titrations. R. MELLET. (*Mon. Scient.*, lxxv, 837, 576.)—This new indicator is 6-sulpho, β naphtol-azo, m-oxybenzoic acid, prepared from the sodium salt. The sodium salt is purchasable as a black powder, with a violet tinge, very soluble in water, forming a blue-violet solution. For use, a 1 per cent. solution of the sodium salt is treated with decinormal hydrochloric acid, drop by drop, until it acquires a red color. Alkalies change it to violet-blue when neutral, or cherry-red when alkaline. The neutral tint is violet-blue, the alkaline cherry-red, and the acid bright red. The liquids to be titrated must be strongly colored by the indicator, contrary to the practice with the known indicators; *e.g.*, litmus, methyl-orange, etc. An acid solution is titrated with alkali until a deep violet-blue color is reached; an alkaline solution is titrated with acid until the violet-blue tone becomes intensely bright red. It is of little use as a paper, for while the neutral (blue-violet) paper is very sensitive to acids, the acid paper (red) is only sensitive to very dilute alkalies, as with strong alkalies it passes directly from bright red to cherry-red, and the toning is not well marked. The advantages of the new indicator are: First, its intense coloring power, which makes the change of color clearly perceptible; second, a very clear change, whatever the volume of the titrated liquid; third, extreme sensitiveness, even for deci- or centi-normal solutions; fourth, sensitiveness in both senses, so that an acid solution can be titrated with a basic liquid, or a basic solution with an acid liquid, with equal precision.

The Action of Sirupy Phosphoric Acid on Alloys. Max Wunder and B. Jeanneret. (*Mon. Scient.*, lxxv, 837, 629.)—Certain metals or alloys obtained in the electric furnace, which sometimes resist the most energetic chemical action, are attacked and completely dissolved when powdered and heated with an excess of phosphoric acid above 1.75 in density. This applies to metallic silicon, zirconium, and tungsten, ferro-titanium, vanadium, silico-manganese, titanium nitride the alloy of ferro-silicon with 23 per cent. aluminum, boron-nickel, and carborundum. In all these reactions the carbon contained in the alloys remains, wholly or partially, in a flocculent condition in the sirupy liquid. The addition of water to these different sirupy liquids does not cause it to precipitate, but entirely dissolves it. On the other hand, the white precipitate obtained from certain alloys of silicium remains insoluble, both in water and in hydrochloric acid.

Mercury Mines of Mexico. Anon. (*Moniteur Scient.*, lxxv, 837, *Mercure* 69.)—In the province of San Luis Potosi there are 41 mines; the greatest quantity of mercury comes from the vicinity of Montezuma, 40 miles north of San Luis Potosi, and the neighborhood of Guadalcazar, 52 miles northeast of that town. It is extracted from metacinnabarite, a black mineral containing 60 per cent. mercury. The mines are open cuts at a height of 200 metres above sea-level, and belong to Mexicans. The yield is about 1,200 flasks of 75 pounds each annually. The mines of Guadalcazar are very old and were known to the Indians before the discovery of Mexico. The Trinidad mine yields 500 to 700 flasks. The minerals are cinnabar and black metacinnabar, and two others, fieroso and acerado.

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INDEX TO VOL. CLXXII.

Agriculture, New use of explosives in (Gunsolus), 153
Anæsthetics, Chemistry of (Baskerville), 113

Barstow, W. S.: Small public service properties and their future, 267
Baskerville, Charles: The chemistry of anæsthetics, 113
Bismuth-silver thermopile (Coblentz), 559
Blast furnace waste, Utilization of (Hagar), 197
Blast furnace waste, Utilization of (Outerbridge), 195
Bone, W. A.: Surface Combustion and its industrial applications, 602
Book Notices:
  Adams, Walter S.: An investigation of the rotation period of the sun by spectroscopic methods, 607
  Barus, Carl: The production of elliptic interferences in relation to interferometry, 607
  Chaplet and Rousset: Le blanchiment, 282
  Church and Bartlett: Elements of descriptive geometry, 95
  Curie, Madame P.: Traité de radioactivité, 609
  Dudley, Charles B.: Memorial volume, 95
  Gerard, Éric: Leçons sur l'électricité, 201
  Leiser, H.: Wolfram, 608
  Meade, Richard K.: The Chemists' Pocket Manual, 281
  Perrine, Charles D.: Determination of the solar parallax from photographs of Eros made with the Crossley reflector of the Lick Observatory, 606
  Russell, Henry Norris: Determination of stellar parallax, 607
  Savoia, Umberts: La metallographie, 282
  Sutton, F.: A systematic handbook of volumetric analysis, 608
  Wietlisbach, Victor: Handbuch der telephonie, 281
  Willis, Bailey, Charles D. Walcott, and others: Research in China, 518
Bradbury, Robert H.: The teaching of elementary chemistry, 163
Bryan, A. Hugh: Composition of American commercial glucose and starch sugars, 337

Calculations, Thermal, simplifying some of the, by the use of the thermal ohm (Hering), 569
Chance, Edwin M.: The examination and physiological action of pathogenic mine atmospheres, 461
Chemistry, elementary, The teaching of (Bradbury), 163
Chemistry of anæsthetics (Baskerville), 113
Coblentz, W. W.: A bismuth-silver thermopile, 559
Coblentz, W. W.: The rôle of water in minerals, 309
Combustion, Surface (Bone), 602
Correspondence:
  Utilization of blast furnace waste (Outerbridge), 195
Crisfield, J. A. P.: The determination of moisture in fuel, 495
Current Topics, 22, 38, 54, 91, 92, 97, 144, 162, 193, 194, 203, 288, 308, 336, 344, 368, 403, 460, 502, 507, 508, 522, 558, 568, 590, 600, 612

Distillation, Fractional (Rosanoff), 527

Electric furnaces (Hering), 55
Electric meters, prepayment, The use of (Vaughen), 253
Electric transients (Steinmetz), 39
Electrical contact, On the duration of, between impacting spheres (Kennelly and Northrup), 23
Electrical methods of intercommunication for military purposes (Squier), 545
Electrolytic corrosion of iron by direct current (Hayden), 295

Explosives, New uses of, in agriculture (Gunsolus), 153

Fluorescence in testing oils (Outerbridge), 591
FRANKLIN INSTITUTE:
  Committee on Science and the Arts, Abstract of proceedings at meetings, June 7, 1911, 93; September 6, 1911, 400; October 4, 1911, 509; November 1, 1911, 601; November 8, 1911, 601
  Library notes, 94, 283, 401, 517, 605
  Membership notes, 93, 195, 282, 400, 511, 603
  Proceedings of the stated meeting, June 21, 1911, 93; September 20, 1911, 399; October 18, 1911, 509; November 15, 1911, 601
  Sections, Proceedings of meetings, 510, 602
FRANKLIN, WILLIAM S.: The principle of relativity, 1
Fuel, Moisture in, determination of (Crisfield), 495
Furnaces, electric (Hering), 55
Foodstuffs, Perishable, The handling, transportation and storage of (Hepburn), 173, 369

Gases, The measurement of (Thomas), 411
Glucose, American commercial, Composition of (Bryan), 337
GUNSOLUS, F. H.: New uses of explosives in agriculture, 153

HAGAR, EDWARD M.: The Utilization of blast furnace waste, 197
HAM, W. R., L. J. LASSALLE and OSCAR F. SMITH: A null method for measuring relative intensities of Röntgen rays, 73
HAYDEN, J. L. R.: Electrolytic corrosion of iron by direct current, 295
HEPBURN, JOSEPH SAMUEL: The handling, transportation, and storage of perishable foodstuffs, 173, 369
HERING, CARL: Electric furnaces, 55
HERING, CARL: Simplifying some of the thermal calculations by the use ot the thermal ohm, 569

Intercommunication, Electrical, Methods of, for military purposes (Squier), 545
International Electrotechnical Congress of Turin (Kennelly), 503
Iron, Electrolytic corrosion of, by direct current (Hayden), 295

KENNELLY, A. E.: The International Electrotechnical Congress of Turin, 503
KENNELLY, A. E., and EDWIN F. NORTHRUP: On the duration of electrical contact between impacting spheres, 23

LASSALLE, L. J., W. R. HAM, and OSCAR F. SMITH: A null method for measuring relative intensities of Röntgen rays, 73
LATHROP, ELBERT C., and OSWALD SCHREINER: The distribution of organic constituents in soils, 145
LEWIS, WILFRED: Machine molding, 227
LIEBER, HUGO: Modern uses and applications of radium, 579
Liquid mixtures, Vapor pressures of (Rosanoff), 527

Machine molding (Lewis), 227
Measurement of gases (Thomas), 411
Mine atmospheres, Pathogenic, The examination and physiological action of (Chance), 461
Minerals, Water in, The rôle of (Coblentz), 309
Molding Machines (Lewis), 227

NORTHRUP, EDWIN F.: An experimental study of vortex motions in liquids, 211, 345
NORTHRUP, EDWIN F., and A. E. KENNELLY: On the duration of electrical contact between impacting spheres, 23
Null method for measuring relative intensities of Röntgen rays (Ham, Lassalle, and Smith), 73

Oils, Practical application of fluorescence in testing (Outerbridge), 591
Organic constituents in soils, Distribution of (Schreiner and Lathrop), 145
OUTERBRIDGE, A. E., JR.: A practical application of fluorescence in testing oils for industrial purposes, 591

OUTERBRIDGE, A. E., JR.: The utilization of blast furnace waste (correspondence), 195

Principle of relativity (Franklin), 1
Public service properties, Small, and their future (Barstow), 267
Publications received, 96, 202, 286, 402, 520, 610

Radium, Modern uses and applications of (Lieber), 579
Relativity, Principle of (Franklin), 1
Röntgen rays, A null method for measuring relative intensities of (Ham, Lassalle, and Smith), 73
ROSANOFF, M. A.: Vapor pressures of liquid mixtures and fractional distillation, 527

SCHREINER, OSWALD, and ELBERT C. LATHROP: Distribution of organic constituents in soils, 145
SMITH, OSCAR F., W. R. HAM, and L. J. LASSALLE: A null method for measuring relative intensities of Röntgen rays, 73
Soils, Distribution of organic constituents in (Schreiner and Lathrop), 145
SQUIER, GEORGE OWEN: Electrical methods of intercommunication for military purposes, 545
STEINMETZ, CHARLES PROTEUS: Electric transients, 39
Sugars, Starch, American commercial, Composition of (Bryan), 337
Surface Combustion (Bone), 602

Tar, Coefficient of expansion of (Weiss), 277
Teaching of elementary chemistry (Bradbury), 163
Thermal calculations, Simplifying some of the, by the use of the thermal ohm (Hering), 569
Thermopile, Bismuth-silver (Coblentz), 559
THOMAS, CARL C.: The measurement of gases, 411

Vapor pressures of liquid mixtures and fractional distillation (Rosanoff), 527
VAUGHEN, F. G.: The use of prepayment electric meters, 253
Vortex motions in liquids, An experimental study of (Northrup), 211, 345

Water in minerals, The rôle of (Coblentz), 309
WEISS, JOHN MORRIS: The coefficient of expansion of tar, 277

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